5. CURRENT MANAGEMENT

All pertinent administrative and technical aspects of WDFW's current management of the high lake fishery in Washington are briefly summarized in the following chapter. At the end of each major section, an assessment is made of current policies and practices. These are followed by recommendations, as appropriate.

Many believe the WDFW is stocking all, or a majority of the "lakes" in the mountains. Nothing could be further from the truth. Of the more than 4700 high lakes and ponds in Washington, at least 2940 (62%) are fishless (see Section 5.4.6), and only about 800 (17%) are periodically stocked. In order to address this unfounded concern about excessive stocking, it is useful to begin with a definition of a lake. As Anderson (1971) pointed out, the terms "lake" and "pond" or "tarn" defy precise definition, therefore he "arbitrarily" categorized his study waters according to a graph similar to Figure 6a. We have adopted this approach as being convenient and reasonable, based on extensive experience with the size and shape of managed waters in Washington. From the figure it is seen that waters with a maximum depth of 3 feet, but an area of about 8 acres would still be considered ponds. Conversely, waters as small as 1 or 2 acres, if at least 12 to 16 feet deep at their deepest point, would still be considered lakes.

The very small ponds and tarns still tend to have maximum depths of 3 to 5 feet (Figure 6b). Maximum depth increases continuously with lake size up to about 160 acres (n=1207). A 2, 5, 10, and 20 acre high lake in Washington tends to have a maximum depth of about 13, 28, 41, and 73 feet, respectively.

The overwhelming majority of alpine and subalpine waters being maintained for trout fisheries in Washington are not only lakes by this definition, but are at least large enough to appear on standard 7.5 minute U.S. Geological Survey (USGS) topographic maps. Waters less than 0.1 to 0.2 acre tend to be omitted from these 1:24,000 scale maps. However, recent work in NCNP documents what experienced high lake fishery management biologists already knew: there are thousands of small ponds and tarns scattered across the landscape that do not appear on 1:24,000 scale topographic maps. Most of these do not support fish, but do provide important, or critical habitat for amphibians and invertebrates (Kezer and Farner 1955; Anderson 1967; Fukumoto and Herrero 1998).

Figure 7a plots the size distribution of lakes and ponds larger than 0.02 acre. This figure includes all waters, with or without fish. Most waters in the current lake and pond database range from 0.2 to 50 acres, but there are a few high lakes that exceed 300 acres (Figure 7a). The size distribution of the waters being managed for fisheries is similar (Figure 7b). Most of these waters have self-sustaining fish populations and are not stocked. The arithmetic mean area of waters in the HLS database is 6.1 acres, however the geometric mean is only 1.5 acres, indicating the vast majority of lakes and ponds are small. About two thirds to three quarters of all waters in the HLS database are less than 3 acres in size (Figure 7a).

5.1 INVENTORY METHODS

Cummins (1972), Johnston (1972, 1973) and Williams (1972) presented methods they had found practical to obtain information deemed essential for fishery management at that time. To date, no "standardized" methodology for high lake surveys has been prepared for use in Washington. A report such as Bahls (1989) might serve as an example. There are many similarities between Bahls' methods, and those used by most WDFW management biologists. Bahls (1989) even cited both of Johnston's 1972 and 1973 reports. A truly standardized methodology is probably not possible as long as district biologists must survey their lakes on their own, given differences in personal hiking ability, if nothing else. It would

Figure 6a. Suggested Curve to be used to Designate Lakes Versus Ponds in Washington High Country.

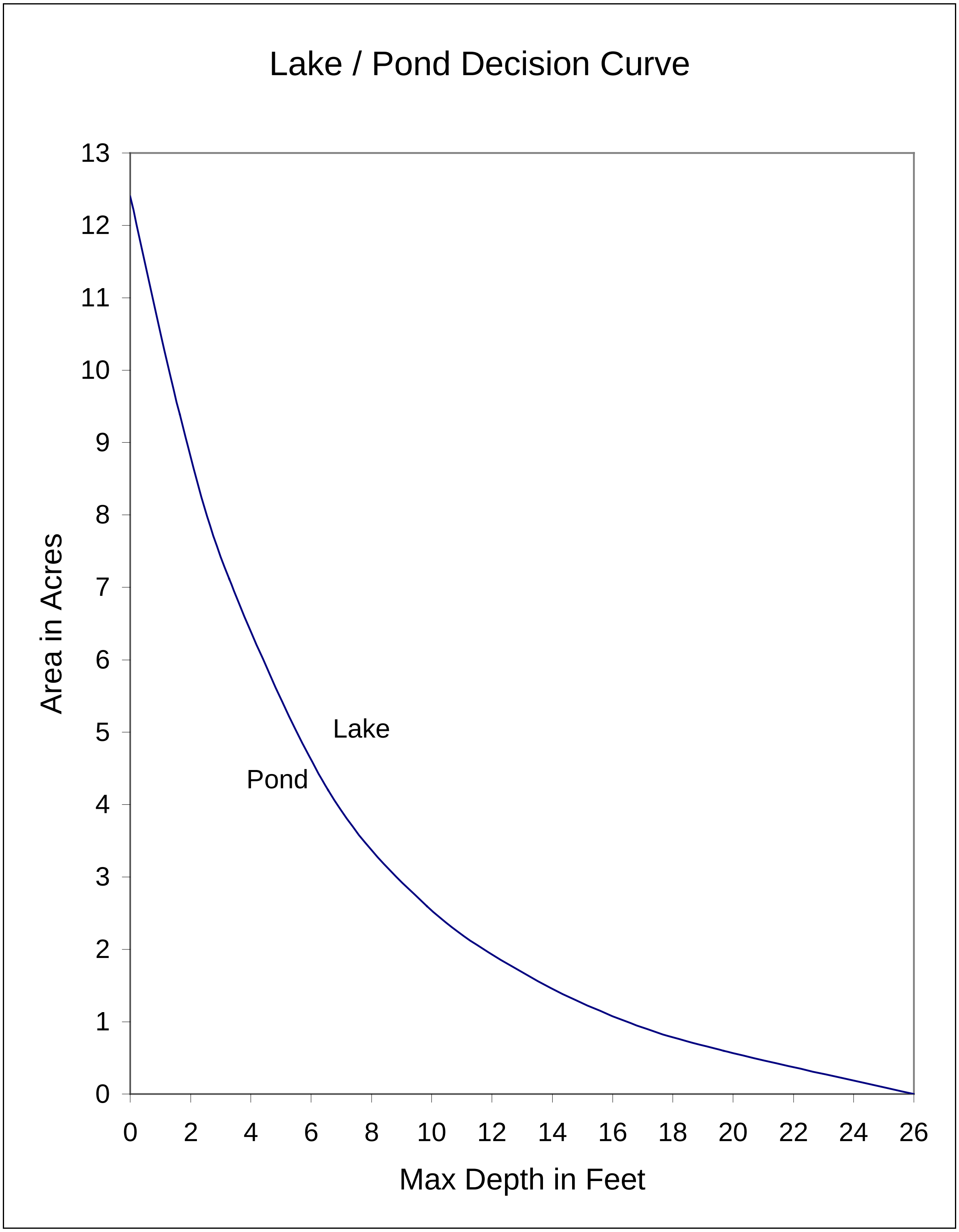


Figure 6b. The Relationship Between Maximum Depth and Area of Washington High Lakes. The number of lakes in each size category is shown.

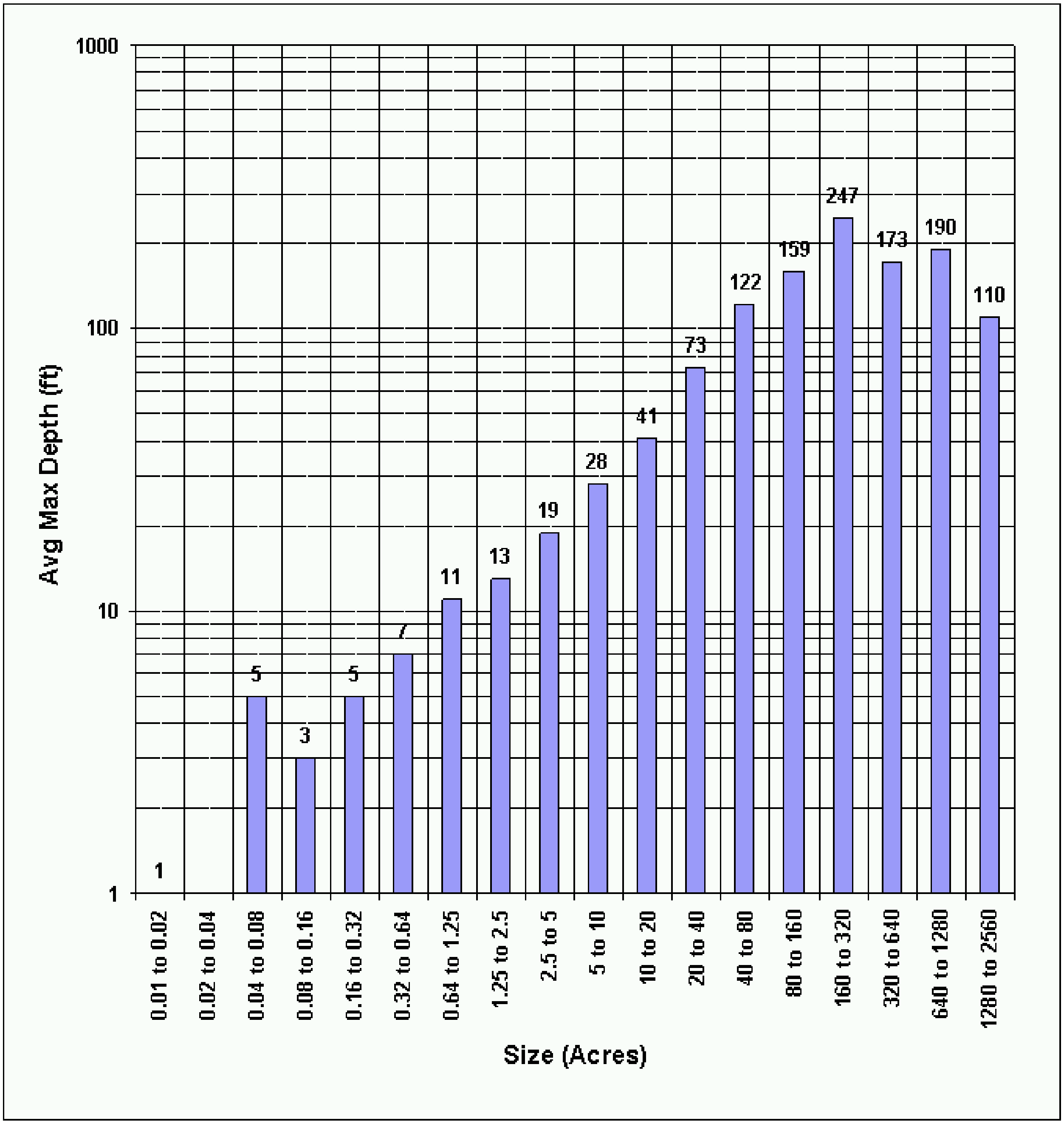


Figure 7a. The Size Distribution of High Lakes and Ponds in Washington (with and without fish).

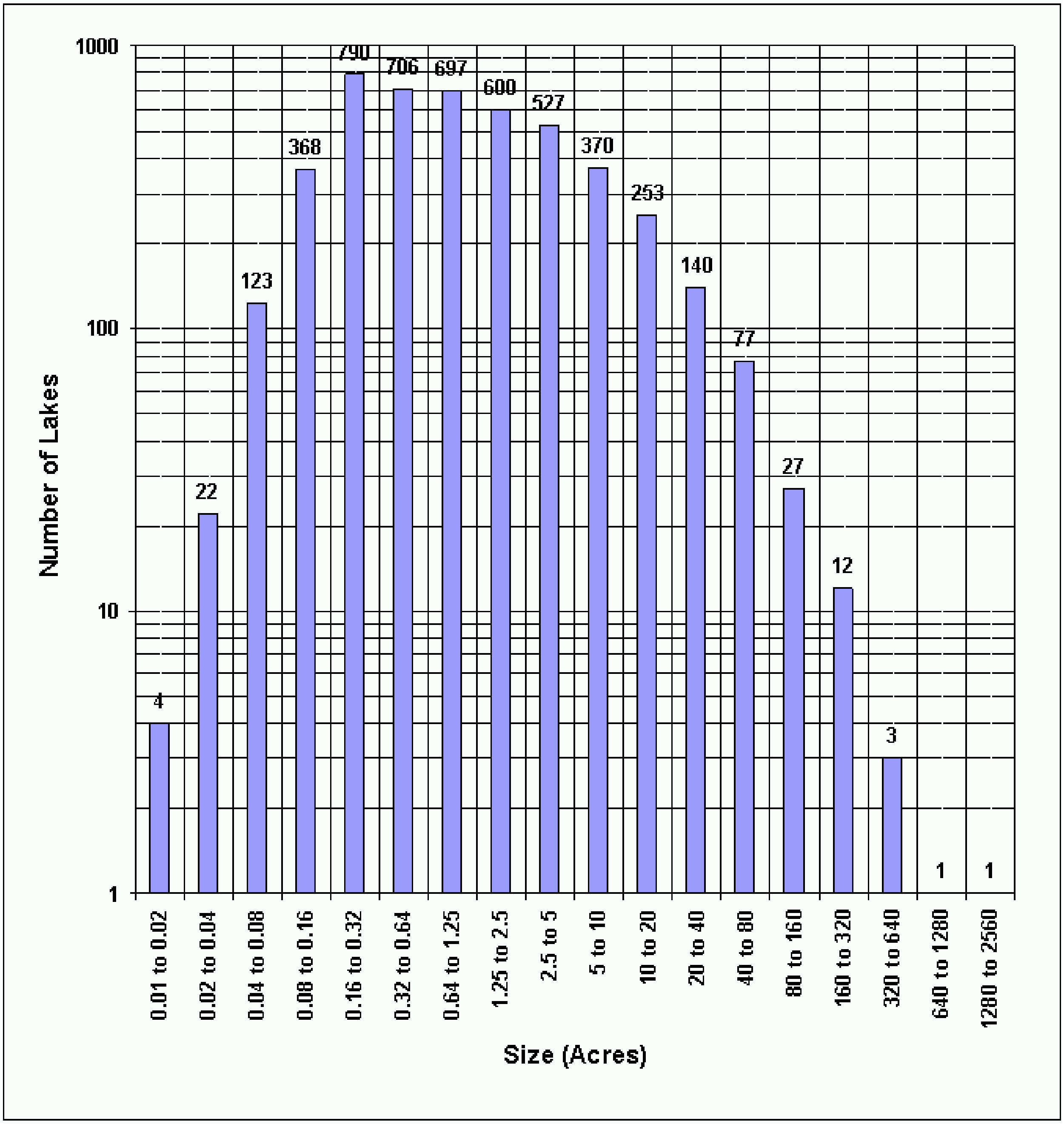
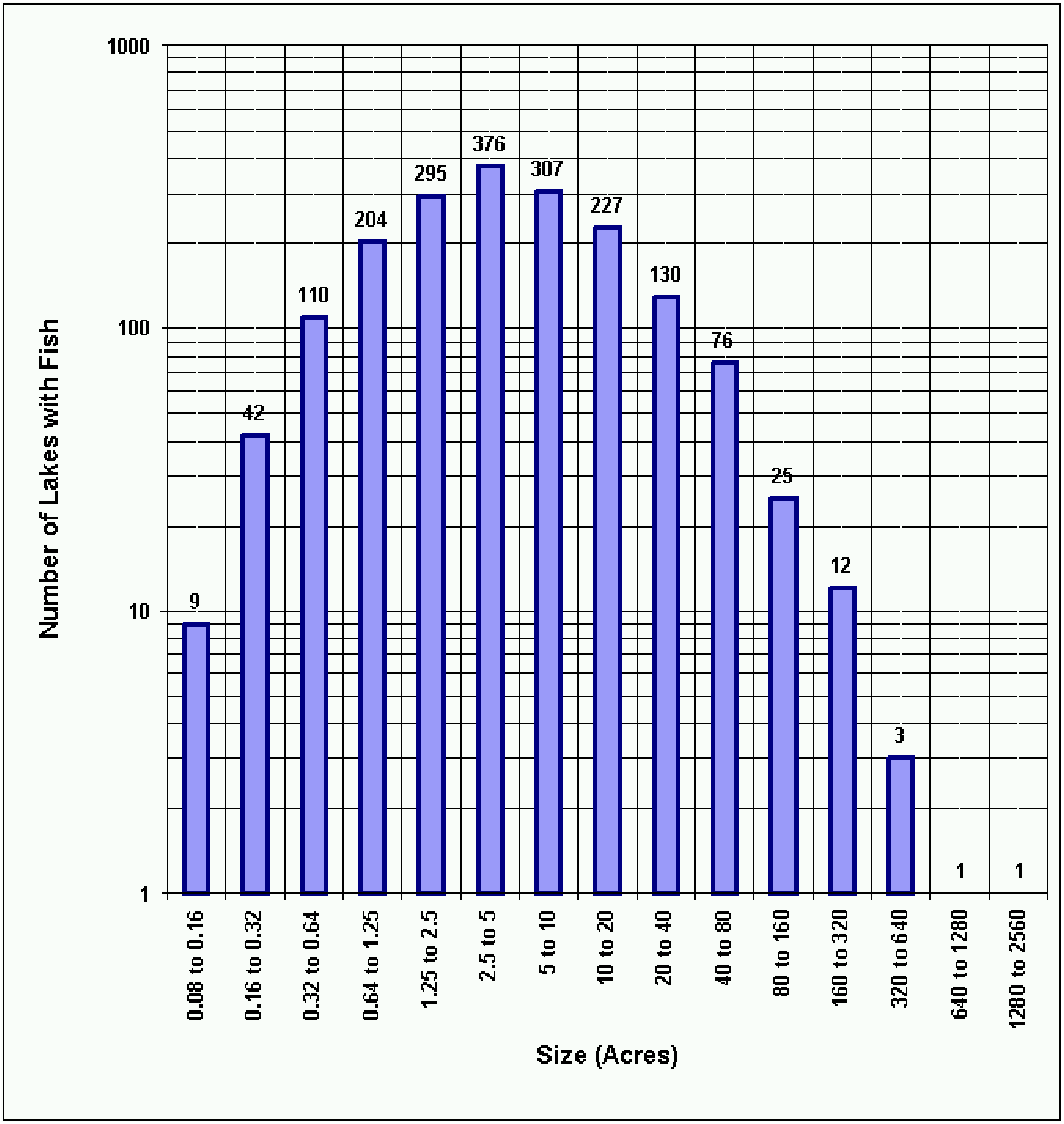


Figure 7b. The Size Distribution of High Lakes And Ponds Managed for Trout Fisheries in Washington. A majority of the waters have self-sustaining fish populations.



certainly be possible to agree on a minimum amount of information, and this has, by and large, been obtained on many lakes. A "minimum" high lake survey methodology for Washington high lakes, perhaps stratified for western and eastern Washington districts, would be a valuable reference, particularly for future district fishery biologists. However, the first step, literally, is to get to the lakes.

5.1.1 Getting There

The first requirement of a successful, or at least productive high lake fishery manager in Washington is to take the long view. With the biota associated with literally thousands of ponds and lakes under WDFW's purview, surveying and cataloguing all of them seemed like an overwhelming task 30 years ago. Fortunately, a number of individuals were willing to take that first step, even if it was up a very steep, brushy slope. Much of the terrain that supports high lakes in Washington is very rugged and geologically youthful. Complicating the task of inventory and surveying is the fact that a majority of the lakes lie within designated wilderness, which limits access in most cases to hiking.

The pack of a solo biologist/hiker, loaded with the minimum gear for one to several nights, may weigh 65 pounds or more. With experience, surveyors can minimize bulk and weight, yet bring a variety of surveying equipment for work on and around the water (Plates 4 to 6). Apart from safety concerns, most WDFW high lake biologists also hiked to their lakes with experienced backcountry hiker/anglers who assisted in the gear toting task, as well as fish collections and biological workup (e.g. Lucas 1989).

To date, the majority of lakes have been accessed on foot or horseback. In some areas outside of wilderness it is possible to utilize helicopters (Plate 7), which, although expensive, have a number of advantages. Careful helicopter trip planning can place one to several surveyors in a strategic location for surveying multiple lakes, and save substantial hiking time, thus defraying the cost of the lease. Some WDFW biologists were also able to obtain donated helicopter air time from a variety of sources. Helicopters of the size shown in Plate 7 can land in an opening as narrow as 35 feet.

As useful as a helicopter is in reducing the effort and time to access remote lakes, it has one serious drawback. One of the most essential indices of angler effort of remote lakes is the time and effort required to get to them. The fishery manager cannot even begin to appreciate this if he/she does not hike to the lake. Personal experience on the route is one of the most important ways a manager can "get a feel" for annual recreational effort, and gauge probable angling mortality (see Section 5.4.2).

5.1.2 The Concept of Survey "Level"

Experience has shown that information on certain physical, chemical, and biological parameters is essential to development of any management plan for high lakes or ponds supporting trout fisheries. The minimum "level" would be that which collects this essential information. Physical information includes lake area and maximum depth; an estimate (or calculation) of mean depth; location and character of tributaries and outlet/s, length accessible to trout, and the amount of spawnable habitat; and the nature of the nearshore lake bottom (littoral zone). Chemical parameters include pH, hardness, total alkalinity, and the presence of any toxic elements, such as heavy metals. Biological information includes presence or absence of fish; the age structure of any population found; growth and condition of fish; and any evidence of successful reproduction, such as fry in spawning areas, or a population age structure that does not correlate with the water's stocking history. Additional biological information is the diversity and relative abundance of invertebrate food resources, and the presence of rooted aquatic plants. Other valuable information that does not fit neatly into these three categories includes access difficulty, and evidence of the level of human use of the lake vicinity.

Plate 4. Light, compact fishing equipment is a pre-requisite for surveying remote backcountry lakes. The blue bag contains a folded nylon raft. Together, the raft and inflating bag weigh 19 ounces. The breakdown rod doubles as a spinning or fly rod.

Plate 5. An assortment of bait, spinning lures, wet flies, and dry flies helps assure success in sampling by hook and line.

Plate 6. An inflatable sleeping pad, placed in the raft, provides back support, and enables comfortable work for hours, even in frigid water. Goat Lake, Middle Fork Snoqualmie River drainage, (27 September 1991).

Plate 7. Smaller helicopters can land in a space no wider than 35 feet, and can transport three men with heavy packs to a strategic jumpoff point. Nine Hour Lake, Middle Fork Snoqualmie River drainage, (8 September 1982). G. Ring Erickson photo.

This basic information can enable a determination as to whether the water needs to be stocked, whether it should be stocked, what fish species may be appropriate, and a preliminary estimate of an appropriate stocking density and frequency. Note, however, that these basic surveys have already been completed on most high lakes or ponds supporting fisheries (Table 4). Additional detail is given in the following sections on the techniques used by local management biologists since 1970.

Table 4. Percentage of Washington High Lakes Supporting Fisheries That Have Received a Baseline Physical, Chemical, and Biological Survey, by County, as of 2001.

(Excluding Lakes in Olympic and Mt. Rainier National Parks and Yakama Indian Nation)

County	Number of Fish-Bearing Lakes	Number Surveyed	Percent Surveyed
Jefferson	15	15	100
Grays Harbor	6	3	19
Mason	16	(ND)[1]	
Whatcom	121	47	39
Skagit	140	55	39
Snohomish	217	80+	37
King	360	323	90
Pierce	57	31	54
Cowlitz	7	7	100
Lewis	74	74	100
Skamania	118	118	100
Yakima	117	32[2]	27
Kittitas	111	0[2]	0
Chelan	223	0[2]	0
Okanogan	108	108	100
Pend Oreille	3	3	100

[1] Information unavailable at time of report preparation.

[2] Most fish-bearing waters have received limited survey, but not a full "baseline" survey of all variables.

5.1.3 Physical Description

The questionnaire survey of most of the biologists who managed Washington's high lakes for the past 25-30 years revealed some diversity of methods. The initial surveys reported by Cummins, Johnston, Lucas, and Williams were fairly thorough. Interested readers should review their reports for specifics, but the various techniques most commonly used are summarized below. A few biologists have not had the time or resources to develop much detailed physical information on their lakes on their own, but some lakes on their districts have been surveyed by the US Forest Service using their Region 6 protocol (Hann and Wall 1992).

Field data forms and explicit procedures were developed and used on surveys on the Olympic National Forest (Johnston 1972), and in the following counties: Whatcom, Skagit, Snohomish, King (WDFW Region Four file data); King and Pierce Counties (Cummins 1973); Cowlitz and Lewis Counties (Lucas 1989); and Okanogan County (Williams 1972). An example of the primary field data form used in King and Snohomish Counties appears in Appendix C.

The field sketch map of the lake or pond is the most important and fundamental information collected on the water's habitat. Most, if not all local biologists retain their baseline survey data in lake by lake files. Information on lake shape, location of inlets and seeps, fish access, location of campsites, soundings and transects, and more are noted on the base map. This is usually transferred to a more refined database or management plan format (Appendix C), or may be prepared as figures in reports such as Lucas (1989), or Deleray and Barbee (1992).

Lake Area

All local management biologists use surface area as a fundamental metric in setting trout stocking rates. Some managers used surface area estimates provided in Wolcott (1965), although a few of Wolcott's areas are known to contain errors, some of which are quite significant. Most of Wolcott's acreage estimates were derived from aerial photographs and use of a polar planimeter. The area of others, particularly "small" lakes, was derived using scaled grids. Wolcott (1965) noted that aerial photos often showed water areas that differed considerably from that shown on some maps. Other WDFW local managers (Johnston, Pfeifer) used aerial photos and/or scaled grids and 1:24,000 topographic maps to determine lake area. These methods are described in basic texts such as Welch (1948). Pfeifer also used a stereo analytical plotter and aerial photographs to digitize lake polygons on most of the lakes in the Snoqualmie, Cedar, and Green River watersheds (WDFW 1994; Reutebuch et al. ND; Plate 8). (All high lakes and ponds shown on 1:24,000 USGS topographic maps of Washington were recently digitized into a GIS layer. This information could be used to update acreage information used by some local managers, although errors in Wolcott (1965) are usually not significant from a fish management perspective.)

Personal experience of the author has repeatedly shown that there is often no substitute for an on-the-ground survey (Plate 9). Lake shape and actual size is often different from that shown on topographic maps, particularly for small water bodies. In most cases, however, a quality aerial photograph of suitable scale (Plate 10) is nearly as good as a ground survey for determining lake area. A number of biologists reported they prepare a lake outline from a topographic map or aerial photo, then make in-field adjustments to correct inadequacies in the preliminary shoreline outline. The ideal approach is to prepare a field map of the lake or pond, and mate that with use of a pair of stereo aerial photographs (Plate 8).

Plate 8. A stereo analytical plotter utilizes two adjacent aerial photos that have been corrected for parallax, and which are controlled, or linked to known GPS coordinates. The system has a high degree of precision; a white dot viewed through the optics corresponds to about 30 feet on the ground. Digitized lake polygons, or attributes such as islands, are logged in files created on the linked computer to enable calculation of metrics such as lake surface area, shoreline length, etc.

Plate 9. Whenever possible, the field sketch map of the lake should be truthed and edited from a vantage above the lake. Prepared lake outlines from sources such as USGS topographic maps make excellent baseline maps to build on. Upper Wildcat Lake with the rugged Melakwa Pass area beyond, Middle Fork Snoqualmie River drainage, (15 September 1984). G. Ring Erickson photo.

Shoreline Development

Shore development refers to the ratio of the actual length of shoreline of a lake to the length of the circumference of a circle the area of which is equal to that of the lake. Although this standard physical measure (Welch 1948) has not yet been shown to be important in setting fishery management objectives in Washington, it is intuitively appealing to believe that lakes with highly irregular shorelines and extensive littoral zone development relative to total lake volume would be more productive. Information to calculate shoreline development was collected on scores of lakes in King and Snohomish Counties, but the relevant data have not yet been analyzed to answer this question. Most local biologists do not determine this measure.

Maximum Depth and Lake Bathymetry

Most biologists obtained depth and bottom shape information on their lake surveys, either by a series of sounding line plumbs, or by running echo sounder transects (Johnston 1972; Plates 10 & 11). At least two of the biologists used both, taking a series of soundings from a raft on the small lakes or ponds, and limiting sounder use to the larger waters. Individual soundings are located on the base field map, which can then be used to estimate the location of depth isopleths for the bathymetric map (Lucas 1989; Deleray and Barbee 1992).

A few of the biologists have had the luxury of time and equipment to develop full maps of the bottom contours of many of, or all of their surveyed lakes (Johnston 1972; Lucas 1989; Deleray and Barbee 1992). Pfeifer produced sounder chart records of transects taken on 98 lakes on the North Bend and Skykomish Ranger Districts (Plate 10; WDFW 1994). All of the strip data have been entered into spreadsheets, but the final step of plotting the data to produce bathymetric maps has not yet been taken. Previous bathymetric survey maps prepared by the USGS (e.g., Bortleson et al. 1976; Dethier et al. 1979) have also been made part of individual lake management files in many of the administrative districts.

High lake bathymetric maps are frequently requested by anglers, but have not been produced for that purpose. Their principal value, apart from giving a better sense of the overall depth, shape, and bottom conditions in the lakes, is to enable calculation of lake volume and mean depth (Welch 1948). Mean depth may have application in models of high lake trout production (Moyle 1949; Northcote and Larkin 1956; Ryder 1982; Prepas 1983). Lake volume is certainly needed if a whole-lake chemical treatment is contemplated (see Section 5.7.1).

Plate 10. Essential components for bathymetric mapping using a chart recorder include a transducer that can be towed behind the raft, a pair of 6-volt batteries that can be wired in series to produce 12 volts, a high quality aerial photo of the area, and the base map outline to establish transect end points. Snoqualmie Lake in the Middle Fork Snoqualmie River drainage is shown on the base map.

Plate 11. A bicyclist's rear view mirror attached to sunglasses allows the surveyor to watch the chart recorder and still maintain a straight course between transect end points, even on large, wide lakes. A constant speed is maintained from one end of the transect to the other. Lower Blethen Lake, Taylor River drainage, (24 June 1992). Laurie Wyatt photo.

Nearshore Area and Bottom Composition

Collection of detail on nearshore area and composition (Johnston 1972; 1973) has largely been limited to lakes surveyed by Cummins, Johnston, and Pfeifer (Appendix A). However, their work represents surveys of hundreds of ponds and lakes, mostly in western Washington. Johnston (1973) and Bahls (1989) originally described the technique, wherein the overall average substrate composition is determined from the water's edge to a depth of about 10 feet (Plate 12). The predominant substrate shoreward of the 10 foot contour is categorized as detritus, woody debris, silt, sand, gravel, rubble, boulders, or bedrock (Appendix C).

The amount of total lake surface area in this zone, as well as from the water's edge to a depth of about 20 feet is also of interest. Although not yet statistically tested from the data collected in Washington, the percent of lake surface area shoreward of the 20 ft or 10 ft contours may correlate with trout growth rates. Adding the nature of the substrate within these zones may also contribute significantly to such a model.

The littoral zone is defined as that portion of the shoreward profile occupied by autotrophic plants (Ruttner 1973). The littoral zone is the outer rim of the lake's euphotic zone, which is defined as the depth at which light intensity is one percent of that incident to the surface (Woods and Falter 1982). Photosynthesis is restricted to the euphotic zone, and the phytoplankton and crustacean zooplankton are most dense in this zone (Reid 1961). The 10 ft and 20 ft depth isopleths chosen by Johnston (1973) are somewhat arbitrary, and almost always include the true littoral in most high lakes due to their high transparency. In many lakes, all of the surface area is over water that is less than 20 feet deep, or even 10 feet deep (Plate 13). It is no surprise that these shallower high lakes and ponds are typically the most productive in terms of trout growth rates, particularly at the lower elevations of the subalpine zone (WDFW file data).

Lake Elevation

Virtually all of the biologists use a combination of published information to obtain lake elevation, such as Wolcott (1965) or USGS topographic maps. High quality altimeters are sometimes used in the field to obtain more precise elevations where interpolation on topographic maps is sometimes required, or difficult. WDFW biologist Bob Pfeifer also used GIS-controlled aerial photographs to determine precise elevations on many lakes in King County (Reutebuch et al. ND).

Plate 12. Littoral zone survey includes mapping of bottom materials and vegetation types, and noting the relative abundance of macroinvertebrates. Lunker Lake, Middle Fork Snoqualmie River drainage, (26 August 1993).

Plate 13. A vantage above the lake allows preparation of an accurate map, showing the nature of the substrate that can often be seen throughout smaller, clear, shallow lakes. Polarized sunglasses greatly facilitate this task. Unnamed lake in the Deception Creek and Skykomish River drainage. Mount Daniel is on the horizon (22 September 1999).

Lake Exposure

Biologists who have collected this information most consistently include Johnston, Lucas, Pfeifer, and Williams. It is reported in compass degrees by first orienting a 7.5 minute topographic map to the magnetic field, then aligning a compass edge to a line running from the center of the lake to the direction of least blockage by mountain or ridge slopes surrounding the lake (often directly opposite the direction of glacial headwalls) (Plate 14). Some of the biologists reported the exposure in non-numeric terms such as "northerly", or a series of directions, such as "north through northeast". Exposure is another physical variable which may not have obvious management applications, but may be an important variable in productivity modeling. Exposure is almost certainly correlated with the open-water season, particularly in western Washington and at the higher elevations, based on empirical observations, and 20+ years of data on snow pack and degree of lake clearance in the 3rd week of July (WDFW file data).

Geomorphic Lake Type

Since there is no obvious and urgent fishery management application of this classification, few biologists have determined it for their lakes. Those who did so on a lake by lake basis were Johnston and Pfeifer. Lucas (1989) gave a generalized description of the geology of his work area, and noted groups of lakes that fell within geomorphic categories.

Watershed Area and Basin Gradient

Most biologists did not determine this for their lake basins. Johnston and Pfeifer did so for lakes in King, Snohomish, Skagit, and Whatcom Counties. Basin areas were determined from planimetric measurement of the lake hydrographic boundary determined from a topographic map. Pfeifer also calculated the basin gradient, defined as the elevation difference (ft) between the lake edge and the highest point in the basin, divided by the horizontal distance (ft) between these same points.

Average Water Level Fluctuation

The average water level fluctuation may be defined as the distance in feet between the lake surface in late summer or fall of an average rainfall year, and the change in vegetation (lichens or brush) seen circumscribed about the lake due to the effects of ice, snow, or high water (Plate 15). After the initial work of Johnston (1973), this measurement was collected by Cummins, Pfeifer, Lucas, and Williams; other biologists whose field data were not prepared in technical reports; and Deleray and Barbee (1992). The value could be biased low if the lake is surveyed before it has reached its late summer low point. However, it is the primary author's experience, based on many repeat surveys to lakes spanning the entire summer, that many lakes attain their ultimate fall low level relatively quickly, and either stabilize, or drop much more slowly after a fairly rapid drop soon after iceout. There are, of course, numerous exceptions.

A management application of this measure occurs in those unusual cases where a lake or pond loses a substantial portion of its surface area or rearing volume by late summer, usually due to subsurface drainage. Stocking densities are based on the average late-season, low-volume surface area. A good example is Hi-Low Lake in King County which drops 5-8 feet annually (Plate 16). Its reduced area, determined from a late season aerial photograph coupled with multiple field surveys, serves as the basis for its fry stocking rate.

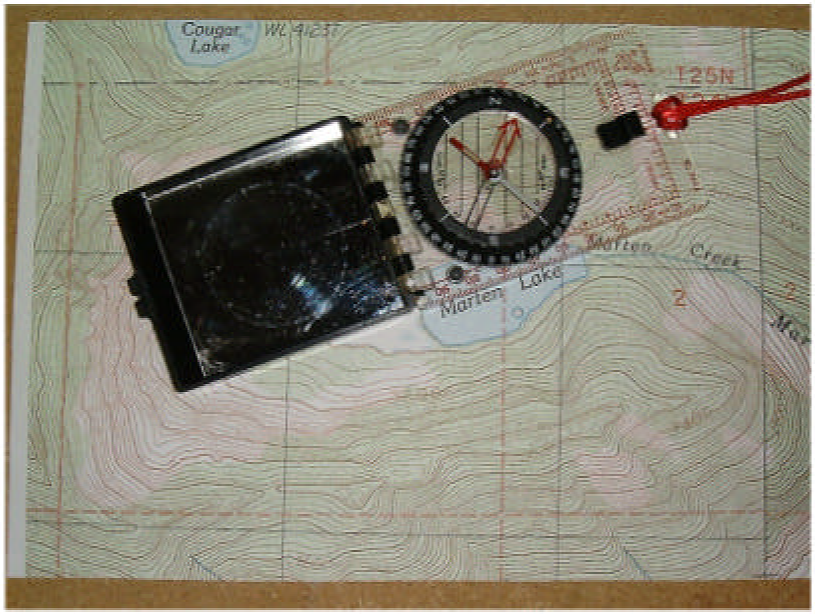


Plate 14. Principal exposure direction is generally along the lake's long axis, oriented away from the glacial headwall.

Plate 15. Lakes that have a significant annual change in surface elevation typically leave distinct marks on the shoreline vegetation that are clearly seen. Nazanne Lake, with Malachite Peak beyond, Foss River and Skykomish River drainage (7 September 1998).

Spawning Area

Most biologists have made physical measurements of the inlets and outlet/s of their lakes, including the lineal distance accessible to trout. The exact manner in which spawning area is reported has varied between the investigators. There is, as yet, no standardized approach. Johnston and Pfeifer measured accessible lengths and mean stream width, and estimated the actual area of spawning habitat by inspection of the substrates (Plate 17). For large or long inlets, Pfeifer approximated spawning area by estimating the percentage of instream habitat that was spawnable, and applying this decimal fraction to the measured total instream area. Others simply reported accessible length, and gave qualitative remarks about the amount of spawning habitat. In essentially all of the technical reports, however, some assessment is made of current or potential reproduction by trout or char. The lake surveys often have both quantitative measurements of spawning habitat, and the biologist's subjective appraisal of its quality, or potential for successful trout reproduction ("None, Poor, Little, Medium, High", etc.).

This assessment is probably the most important one made in the baseline survey of every lake. Contrary to published misinformation (Bahls 1992), WDFW biologists have made this determination on a high percentage of their lakes (Table 5). (See also Section 5.1.2.)

Table 5. Percentage of Washington High Lakes Managed for a Trout Fishery that are Stocked, and in Which a Determination of Fish Reproductive Status has Been Made, by WDFW Administrative Region, as of 2001. ("Lakes" May Include Some Ponds, Per Figure 6a.)

Administrative Region	Number of High Lakes Managed[1] for a Trout Fishery	Number of Lakes Periodically Stocked[2]	Number of These Lakes Where Trout Reproductive Status[3] is Known (%)
1	2	1	2 (100)
2	301	301	260 (86)
3	158	108	158 (100)
4	776	225[4]	535 (69)
5	206	95	206 (100)
6	44	44	44 (100)
All Regions	1,487	-----	1205 (81)

[1] A management decision is often to allow reproducing fish to remain in a lake; in that case it is being managed for a fishery, even though stocking does not occur.
[2] From Parametrix (2001), and estimated for Chelan County from Larry Brown database.
[3] Reproductive status includes: no fish present; fish present but not reproducing; or some level of reproduction.
[4] King and southern Snohomish Counties only; information was unavailable from the north half of Region Four when this report was prepared.

Many of the management biologists have baseline survey maps of most, or all of their managed high lakes. Exceptions are lakes in Chelan, Yakima, Kittitas, and northern Snohomish Counties, where a relatively high percentage have not yet been physically surveyed at the appropriate professional level. (It is important to note that even in these counties, angler reports have often enabled deduction of the presence of reproduction.) The line drawings are stored in lake-by-lake folders or binders of various kinds. The basic maps include the location and orientation of inlets and outlets, and the location of barrier falls.

Plate 16. Lakes like aptly-named Hi-Low, in the Middle Fork Snoqualmie River drainage, can lose a significant amount of surface area over the course of the summer and fall. The high water mark was clearly seen on (26 August 1993).

Plate 17. Many lakes can have extensive inlet systems such as this at Elbow Lake in the Middle Fork Snoqualmie River drainage. Sediment from coarse sand to large gravel may be spawnable, but most smaller trout and char prefer material of the general size range seen here (8 September 1982).

Several of the biologists have used a finer scale in mapping their inlets, differentiating "seeps" from inlets having better-defined channels, or perennial flow. Seeps may be defined as having a bank width of less than 4 inches, or an undefined channel (Plate 18).

Attention paid to in-lake spawning habitat has varied among the field biologists, and underscores the need for an agreed-to standardized approach to baseline lake surveys. While the presence of trout or char reproduction can almost always be deduced by comparing the fish population age structure with the water's stocking history, it is very important to know where the spawning is occurring. This information is critical if reproduction control measures are contemplated. If the only spawning area is a small patch of gravel in one inlet, for example, it may be possible to greatly diminish reproductive success by constructing a fish migratory barrier out of natural materials readily at hand (talus pieces, large woody debris, etc.).

Locating the site/s of spawning is often challenging, especially if it is occurring within the lake. Effective, or even excessive fry seeding can occur from as little as a few square feet of spawning area. These sites are often scree or alluvial fan deposits at the base of steep slopes or inlets (Plates 19, 20). The inlets need not be perennial, since redds are often constructed within the lake proper. A great deal of precision in the measurement of such habitat is not essential; what is essential is some estimate of in-lake spawning area, usually made visually, to account for its existence (Appendix B, C). Documentation of its existence can prevent future stocking mistakes (wrong species or strain) that can lead to virtually irreversible fish reproduction problems (see Section 5.4).

Water Temperature

Lake water temperature is another measure which has not been collected in a standardized manner in Washington. Most biologists collect surface temperature, but the point of collection may be from shore, or offshore, as from a raft. Some also take readings midway in the water column, or near the bottom at the lake's deepest point. Although thousands of readings have been collected over the years, the data have not been analyzed in ways that identify the most valuable or appropriate manner of collection. From a management standpoint, an estimate of the mean summer water temperature has potential value as it has been correlated with trout growth. Donald et al. (1980) found a significant correlation between the weight of Age-5 eastern brook trout and midsummer water temperature, defined as the mean for the 2 to 10 meter depth zone, collected between mid-July and the end of August.

Sufficient "random" surface water temperature values have been collected to give managers a general idea of when lakes will warm to a point where transport water temperatures and temperature shock may be a concern for air-dropped trout fry. In-season monitoring of the time of iceout and weather patterns are part of the "tools" needed by experienced fishery managers to avoid unnecessary stocking mortality, and imprecision in population management. (This concern is somewhat assuaged by observations made on air-dropped fish into Kelcema Lake, in Snohomish County (Pfeifer 1986a). Although the lake surface water temperature was 70^{o} F, fry had sounded from the surface within 15 seconds, and there was no evidence of temperature shock, or apparent delayed mortality in the first 30 minutes. More of these kinds of observations should be made.)

Plate 18. Seeps may be seasonally dry, or may range from damp to carrying a very small flow. The flow volume is too small, and the depth is too shallow to support even small spawners.

Plate 19. Large, long talus-filled chutes or rockslides that support snowfields late into the summer often produce subtle springs or upwelling at their base (see Plate 20). Porous, coarse-grained sediments beneath the larger talus blocks can effectively convey considerable water volume to the lake with no emergent surface flow. Big Snow Lake, Middle Fork Snoqualmie River drainage, (14 August 1994).

Lake surface water temperatures should always be collected offshore, and well away from the influence of inlets. The ideal is a top to bottom temperature profile, but secondary goals are to identify the depth of the epilimnion, or minimally, to take readings 2 inches below the surface, and 3-5 feet below the surface. (Surveys conducted by the USGS in the 1970s provide excellent temperature profile data (Figures 8a,b) on many waters that were subsequently incorporated into wilderness areas (Bortleson et al. 1976; Dethier et al. 1979). Most WDFW biologists have incorporated this kind of high quality information, obtained by others, into their lake files.)

5.1.4 Chemical Description

Parameter lists and collection methods are even less standardized for chemical survey data than physical data. Several management biologists noted they do not need the information to make routine management decisions (e.g.,, stocking rates), and do not obtain the information unless there is some potential problem with water chemistry that needs attention (e.g., Pfeifer and Peacock 1987). The management uses of chemical data from high lakes fall into three general areas:

- Explanation of a water's inability to support fish;
- Monitoring of parameters sensitive to anthropogenic sources of acidification; or
- Classification or scaling of waters as to their potential for trout production.

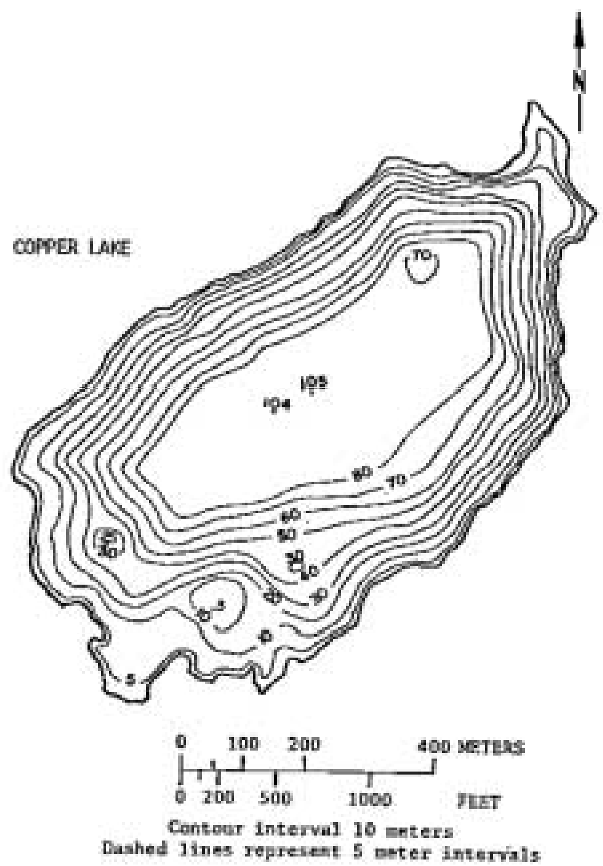
5.1.4.1 *Chemical Limitations*

There is very little need for this type of information in Washington for high lake fishery management. Most biologists have information in regional files that explains why certain lakes cannot support fish. These lakes are often located in mining districts, or lie in basins with naturally high levels of mineralization (Pfeifer and Peacock 1987). Heavy metals are the chemical constituent that most often limit fish survival in these cases.

5.1.4.2 *Acidification*

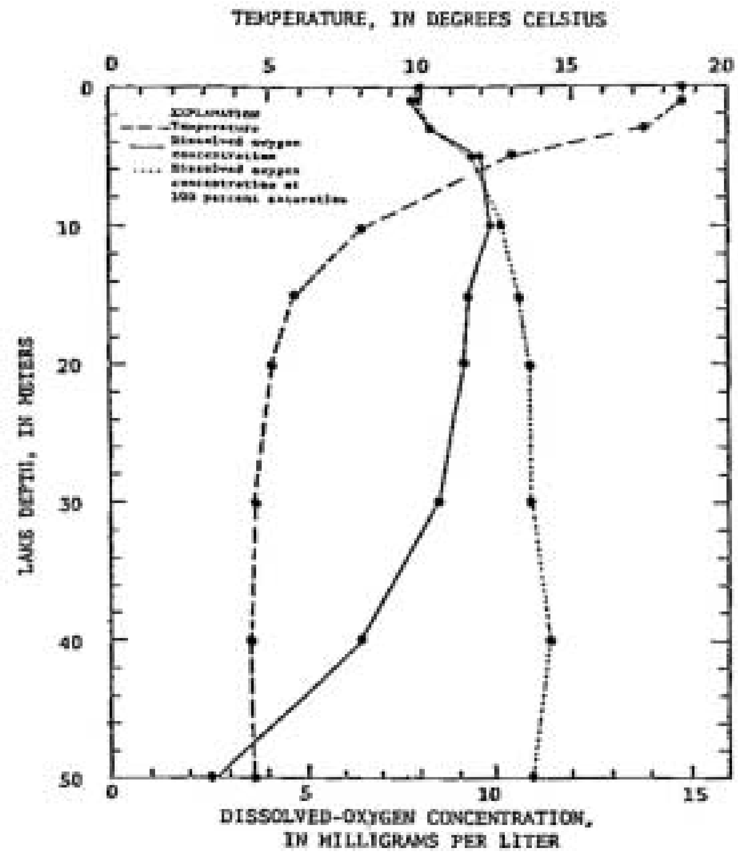
There is great concern by federal land and water managers over the potential for many lakes in Washington's Cascade Mountains to become acidified due to their extremely low acid neutralizing capacity. Considerable field research has occurred on this subject (Haines 1981; Logan and Duncan 1981; Lindstrom et al. 1984; Welch and Spyridakis 1984; Welch et al. 1984; Melack et al. 1985; Welch et al. 1986; Roberts et al. 1986; Welch et al. 1991). Unfortunately, collection of reliably precise information on parameters such as pH has been a challenge, even using sophisticated field equipment (Gall 1998). Most WDFW biologists have collected pH readings for less-demanding purposes, using drop titration and colorimeter methods which are only accurate to 0.25 pH unit, and require visual interpolation to reach that level. While this is precise enough for fishery management, it may not be for more rigorous analyses or early warning detection of changes (Boyd 1980). Very few biologists have the pack space or lab analysis budgets to pack out water samples. However, given these limitations, the many baseline readings of pH, taken *in situ* by biologists in the last 30 years, may still provide a valuable benchmark for detecting relatively gross changes in pH over extended time periods. A few lakes have been sampled which exhibit remarkably low or high pH values that at least partially explain their inability to support trout, but these are likely natural conditions.

Figure 8a. Bathymetric map of Copper Lake, King County, Washington, prepared by the U.S. Geological Survey, 1978.



Copper Lake, King County. From
U.S. Geological Survey, August 4, 1978.

Figure 8b. Dissolved oxygen and temperature profiles of Copper Lake, King County, Washington, prepared by the U.S. Geological Survey, 1978.



Copper Lake, King County. From
U.S. Geological Survey, August 4, 1978.

5.1.4.3 *Lake Productivity Evaluation*

Despite questions of utility, and sometimes inconsistent collection, several parameters have been collected in a great many high lakes in Washington, and quite consistently in some districts. These include pH, total alkalinity, hardness, and conductivity. As with temperature, studies conducted by others (Bortleson et al. 1976; Welch et al. 1986) are often incorporated into WDFW lake files. Johnston (1973) and Pfeifer have amassed a large amount of spot sample information on a lengthy list of lake chemical constituents, either by their own collections and in-field processing, by bringing samples from the field for lab processing, or by accumulating information published by others. This data set has not been analyzed to determine whether any parameters, or some subset, are correlated with trout or char growth in Washington's high lakes, although this has been attempted by others in other areas (Donald et al. 1980).

Jones and Hoyer (1982) found chlorophyll-*a* to be a stronger correlate with sport fish harvest (kg/ha) than total phosphorus, alkalinity, or the morphoedaphic index. However, their data was taken from lowland lakes and reservoirs, not high lakes. Determination of chlorophyll-*a* concentrations requires collection of a field sample in a rigorous manner, and subsequent lab processing. While it may be a useful correlate with trout growth, its collection and cost of processing makes it an unlikely tool for routine classification of high lakes by field biologists. Wagner and Parker (1973) reported similar logistical and sampling problems with primary nutrients, and stated: "The energy pathways involved (in lake fertilization) are very complex, and this complexity may make it impossible to always find any direct relationship (to) fish yield".

Individual chemical constituent measurements may have little or no utility for classifying Washington high lakes in terms of trout production capability. However, they may have considerable value as part of a suite of variables analyzed using techniques such as multiple regression (Donald et al. 1980), or multivariate analysis (ter Braak 1986; Infometrix, Inc. 1994). Total dissolved solids, or its correlate conductivity, seem to have the most potential as individual metrics, but they may be even more useful if combined with several other known correlates with trout growth (Donald et al. 1980). Conductivity is easily measured in the field, and may be most valuable as an index of potential trout growth in lakes where their numbers can be controlled. Conductivity can be measured *in situ* with sufficient accuracy and precision with an easily portable instrument (Plate 21). Conductivity can be substituted for total dissolved solids in the morphoedaphic index (MEI; Ryder 1982). The MEI may be an equally, or more powerful index of potential trout production than chlorophyll-*a* or TDS alone, but its derivation requires a measure of the lake's mean depth. It is for this reason that many lakes were re-surveyed for total volume, area, and mean depth by Pfeifer in King and Snohomish Counties. Analysis has not yet occurred on the large amount of field data already collected by Pfeifer and Johnston on trout growth from lakes where stocked trout densities were known, and conductivity (and other variables) is also known. Completion of this data analysis may provide a very useful index of potential trout growth in lakes throughout the Cascades and Olympics where trout or char reproduction is not a problem.

General Field Chemical Methods

Methods most commonly used by WDFW fish biologists to collect water chemistry data are described below.

pH

Biologists who have been able to conduct baseline surveys on their high lakes collect a surface water sample from near shore, or from a raft, and analyze pH with a wide range indicator solution and a color comparator (Plate 22). In some cases, where equipment is available or may be borrowed, a Hydrolab

Plate 20. The sediment and scree slope at the base of the rockslide seen in Plate 19 provides pocket gravel and coarse sand that is spawned by west slope cutthroat. The size of the material is scaled by the black and white mechanical pencil at the water's edge, bottom center. The sediment slopes into deeper water at upper right. Big Snow Lake, Middle Fork Snoqualmie River drainage, (14 August 1994).

Plate 21. Conductivity readings of adequate precision can be taken with a light-weight, portable unit that is easily packed. The unit is calibrated at the beginning of each season with a highly buffered stock solution of known conductivity.

(Plate 23) has been used for pH, as well as other parameters. Due to its size and weight, no WDFW field biologists have packed a Hydrolab into wilderness waters on a routine basis. Lacking regular assistants, most biologists are not willing to substitute other packed gear or supplies to gain the precision it provides.

Baseline pH readings should be standardized as to method of collection, and time of year. Detailed studies of acidification pulses have shown that samples aimed at detecting acid input pulses should be collected at the time of iceout to sample the waters entering the lake from the surrounding snow pack (Welch et al. 1984; Gall 1998). Otherwise, samples may be collected at most any time during the ice-free season. Bahls (1989) recommended a near-surface shallow water sample, and one from near the bottom at the lake's deepest point. From a fishery management perspective, a mid-lake (or well offshore) sample from near the surface should be adequate. Sampling near inlets should be avoided, as well as during rainstorms.

Alkalinity and Hardness

Most WDFW biologists have used the popular Hach Chemical Company Model AL-36B field water chemistry kit components to analyze for alkalinity and hardness (Plate 22). The kit's precision for these parameters is 7 and 14 mg/L, respectively. This may be suitable for broad categorization of lakes, but the data collected to date have not been analyzed for this purpose. Water samples have generally been collected in the same manner and place as for pH (surface water, near shore or offshore). While Johnston (1972) used both the Hach AL 36-B kit and the more precise DR-EL portable laboratory (Midkiff et al. 1972; Boyd 1980), the latter kit's components are generally too bulky and heavy for lakes that must be surveyed using backpack methods.

Conductivity

While some Washington high lakes have been sampled at both the surface and at depth for conductivity (Bortleson et al. 1976; Dethier et al. 1979; Deleray and Barbee 1992), most WDFW biologists (primarily Johnston and Pfeifer) have taken readings in the lake's surface water near shore, or from a raft. In most cases conductivity readings have only been taken on one date at each lake.

Plate 22. Components of several Hach Chemical Company test kits can be packaged in waterproof containers in the backpack. The reagents and methods are not highly precise, but are accurate, and are suitable for general baseline determinations and fishery management. The wide range pH indicator solution is replaced annually to assure accuracy. Reagent solutions can be taken in small quantities to hold pack weight down.

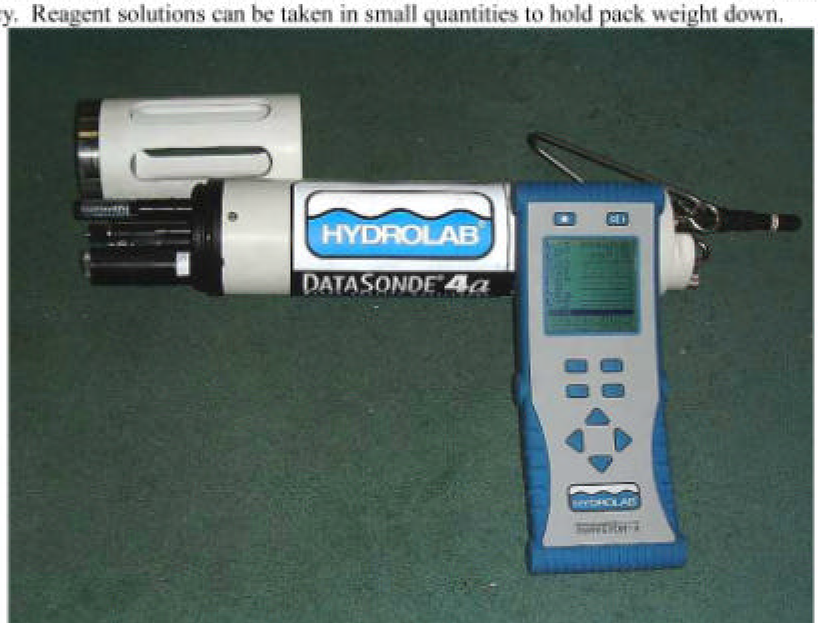


Plate 23. When necessary, greater precision can be obtained on various parameters through use of a high quality instrument, such as a Hydrolab. Packing gear of this volume and weight is generally not practical for single individuals, unless water quality information is the primary objective.

5.1.5 Biological Description

Biological data collected at Washington high lakes can be categorized as relating to nearshore vegetation; lake invertebrates; evidence of fish reproduction; fish age, growth, and condition; fish diet; general fish abundance; evidence of amphibian use; and notes or comments on wildlife use of the lake basin.

Nearshore Vegetation

Some biologists have collected and mapped this information, and some have not. Vegetation was mapped or verbally described for all lakes in the Olympic National Forest (Johnston 1972, 1973). Williams provided verbal descriptions of vegetation for lakes in the Okanogan region. Cummins has taken notes on vegetation on lakes surveyed in Yakima and Kittitas Counties. Limited amounts of this information have been collected in Skamania or Chelan Counties. Biologists working the west side of the Cascades (Lucas, Cummins, Pfeifer, Johnston) have obtained this information for a very large percentage of the lakes supporting fish, and many lakes that do not.

The named westside biologists estimated areas covered, or percentages of lake surface area or littoral area that supported emergent vegetation. Some also mapped their distribution on a field map of the lakes. Species typically seen and noted include freshwater mosses, sedges, aquatic grass, water shield, and lilies (Plates 24, 25).

Most biologists have not noted or mapped the terrestrial nearshore vegetation. Pfeifer and Johnston have developed this information for many lakes in King, Snohomish, Skagit, and Whatcom Counties from aerial photographs and field surveys. Its pertinence to fishery management decisions has not yet been determined, but the information may play a role in analysis of factors that may affect trout production (Wissmar et al. 1977).

Lake Invertebrates

Again, methods used by the various biologists have varied significantly, and no standardized methods have been established agency-wide. Table 6 shows the kinds of invertebrate information available from Washington high lakes, by county, and relevant references or data sources. This is followed by a general description and discussion of the methods that have been used to obtain information on each type of invertebrate.

Plate 24. Some relatively shallow, lower elevation subalpine lakes develop diverse plant communities. These commonly support a relatively luxuriant invertebrate community. It is important to map these plant beds accurately. Shallow plant beds are known to serve as refuge for amphibian larvae, as well as adults. Stocked trout and salamanders have coexisted in this lake for many decades. (There is no reproduction by the trout.) Merlin Lake, Middle Fork Snoqualmie River drainage, (3 September 1984).

Plate 25. Extensive areas of emergent rushes, such as seen here at the inlet end of Myrtle Lake, are also very important as refuge and habitat for amphibians and fish food organisms. Big Snow Mountain rises beyond. Middle Fork Snoqualmie River drainage, (2 September 1984).

Table 6. Types Of Invertebrate Data Collected on Washington High Lakes, by County

County	Zooplankton	Benthic Macroinvertebrates	Amphibian Eggs or Larvae	Quantitative Collections
Whatcom	Yes [1,2,3]	Yes [1,2,3]	Yes [1,3]	Yes (a)
Skagit	Yes [1,2,3]	Yes [1,2,3]	Yes [1,3]	Yes (a)
Snohomish	Yes [1,2]	Yes[1,2]	Yes [1]	Yes (b,c)
King	Yes [1,2]	Yes[1,2]	Yes [1]	Yes (c,d)
Pierce	No	Yes[1,2]	No	No
Yakima	Yes [1,3]	Yes[1,3]	A few observations and notes	No
Kittitas	No	Yes (few)	A few observations and notes	No
Chelan	No	No	No	No
Okanogan	Yes[1]	Yes[1]	No	No

[1] Qualitative assessment of general abundance; notes on taxa present.
[2] Samples collected by consultant or USFS.
[3] Surveyed as part of academic or ecological studies
[3] Deleray and Barbee (1991), selected lakes in Yakima Co.
[a] Liss et al. (1995).
[b] WATER (1993) – in cooperation with USFS..
[c] ZP's Taxonomic Services (1999) – in cooperation with USFS.
[d] Rowe-Krumdick and Matthews (1991)

Zooplankton

Biologists responsible for lakes in most counties made at least qualitative observations on macrozooplankton abundance during their baseline lake surveys. An effective technique is to hold a white raft paddle in the lee of a raft, and slowly extend its position to arm's length (Plate 26). The white surface makes an excellent reflective surface over which even relatively small copepods and cladocerans are visible. Large, red calanoid copepods such as *Hesperodiaptomus* are readily apparent, and general abundance can be gauged (particularly after some experience). Some biologists made vertical hauls with plankton nets in deep water, and horizontal hauls in nearshore areas (Lucas 1989; Deleray and Barbee 1992). It is recognized that even these methods are not quantitative (Edmondson and Winberg 1971).

Semi-quantitative samples of zooplankton have been made in recent years at numerous lakes on various national forests in Washington, using the Region 6 protocol (Hann and Wall 1992). In some cases collections have been made by private consultants (WATER Environmental Services Inc. 1993, 1994; ZP's Taxonomic Services 1999). In-depth studies have been accomplished on many lakes in North Cascades National Park, affecting waters in Whatcom, Skagit, and Chelan Counties (Liss et al. 1995). WDFW biologists obtain this information, and incorporate into their lake files. The relevant application of this information is exemplified by the observation that low-density trout stocking does not result in elimination of large, conspicuous zooplankton forms in Washington high lakes (Divens et al. 2001).

Littoral Macroinvertebrates and Gammarus

Biologists in most areas have made at least some qualitative appraisal of macroinvertebrate presence in their lakes (Table 6). Methods used differ somewhat, but most investigators visually searched the shoreline areas, and took notes on taxa seen, and relative abundance (Plate 12). Some (Johnston, Cummins, Pfeifer) mechanically disturbed the substrate and used a dip net or screen to augment the visual substrate scanning. Their results are reported or maintained as office records in various forms; see Appendix D for a typical example.

Deleray and Barbee (1992) used nets to sweep a minimum of six shoreline areas at each of 32 lakes in Yakima County. Lakes in four national forests in Washington have received more detailed sampling under the USFS Region 6 protocol (Hann and Wall 1992). Liss et al. (1995) applied rigorous sampling techniques to many lakes in North Cascades National Park. WDFW biologists have acquired this information, and make it a part of their lake files.

Invertebrates that are in low abundance, and are therefore difficult to collect (e.g., *Pisidium*) are sometimes observed in trout stomach contents. These observations augment the findings of the shoreline searches.

Evidence of Fish Reproduction

Most, if not all of the district fish biologists determine the presence of natural reproduction through one or more of the following means:

- Reconciliation of the observed age or size composition of the population with the stocking record;*

- Observation of fry in the lake or in spawning areas;

- Angler reports of the above kinds of information (preferably with follow-up field verification).

*Note: In many cases a determination of reproduction hinges on the accuracy of the stocking record. Multiple age groups in the fish population, and equivocal information on spawning habitat shift the evidentiary dependence to the stocking record. This is probably the most important reason for rigorous accuracy in annual stocking records, and the need to ferret out errors from the historical record as much as possible (see Section 5.5.1). It is easy to see how bootleg (illegal, unauthorized) stocking by ignorant or unlawful members of the public can make the determination of reproduction more difficult. The presence of young fish, or fish whose age does not jibe with the official stocking record, can lead an inexperienced biologist to assume they were the result of reproduction.

It is relatively easy to make a determination of active reproduction, discounting for the moment difficulty in accessing remote lakes, or being unable to obtain a fish sample on an individual sampling trip. The latter two circumstances, significant time commitments to access and survey remote lakes, and the frequent need to make repeated trips to obtain confirmation of a fishless condition, are the difficult aspects of this task. However, if a gill net set or two, and multiple hours of lake observation and angling fail to produce any sign of fish, especially on a second or third trip, it is a fairly safe conclusion that if any reproduction exists, it is at a very low level. This can be supported by a habitat survey that shows little or no available spawning habitat.

Most of the lakes being managed for trout fisheries have long stocking histories, and many years of angler reports (see Sections 5.5.1 and 5.2.1). These often provide sufficient information to verify active reproduction, or are a strong reference to augment one to several sampling trips for those few remaining managed lakes or ponds where this question has not been answered (Table 4).

Fish Age, Growth, and Condition

All WDFW biologists routinely collect length information, either directly during their own surveys (e.g., Johnston 1973; Cummins 1973), or from angler reports (Section 5.2.1). The manner in which the information is stored, however, varies among the districts. Some maintain the information in spreadsheets, paper files, data notebooks, or annual Dingel-Johnson reports. Age and growth information from lakes in Chelan, King, and Snohomish Counties has been logged into electronic databases (Section 5.3.3). Most lengths collected are total lengths, but this has not been set as a statewide standard. Units (English versus metric) have also not been standardized, although some biologists prefer metric for its greater precision, and the values are easily converted to English units later, if needed. (See also Section 5.2.1.)

Fish age and growth determinations are made based on scale or otolith samples, unless the age of the fish is known based on the stocking history. Storage of these data varies among the districts, similar to length data. There has been very little in-depth analysis of age and growth characteristics among species, strains, or geographic lake districts. Technical reports (e.g., Johnston 1973; Deleray and Barbee 1992) generally report means and ranges of lengths observed, sometimes by age group, in a tabular format.

Wet whole weight is collected from fish by some biologists, but not all, or inconsistently by some. The availability of suitably precise scales that could fit in a stuffed backpack prevented broad collection of fish weights until the mid- to late 1980s. Deleray and Barbee (1992) used lightweight Pesola spring scales (Plate 27), which were also noted by Bahls (1989). All fish collected by Pfeifer in King and Snohomish County lakes since 1991 were measured to the nearest gram using these scales, resulting in a database with 1747 records for fish lengths and weights in that district (Section 5.3.3). These scales have recently been adopted by the Washington State Hi-Lakers as an integral part of their mission-oriented volunteer high lake survey program (Section 5.2.1).

Strict condition factors (Anderson and Neumann 1996) have been calculated in some districts (Johnston 1973; Deleray and Barbee 1992). Johnston and Pfeifer have large databases of length and weight data from King, Snohomish, Skagit, and Whatcom County high lakes that could (or will) be utilized to calculate these indices. (Also see Section 5.2.1.)

Most WDFW biologists have used qualitative indices of fish condition since 1970 (Cummins 1975; Lucas 1989; Williams 1972). These have generally included a subjective appraisal of overall plumpness or robustness, plus inspection for internal visceral fat reserves (Plates 28, 29). While these are useful yardsticks for professional angler/biologists, they should be augmented with a standardized, accepted approach to measuring fish condition, mindful of the fact that most indices vary with the season (Anderson and Neumann 1996).

All WDFW inland fishery biologists are quite familiar with “stunted” fish populations, whether they are of eastern brook trout (most common), Kamloops rainbow, or westslope cutthroat. Calculation of condition indices is largely an academic exercise for these populations, where fish have been termed “pin-headed” or “snakey” or “emaciated” (Plate 30). However, Pfeifer has collected length and weight data in

Plate 26. Large, conspicuous zooplankton are often very patchy in distribution in large, very clear lakes such as Caroline. Their relative abundance in the lake's top layer can be checked, as hook and line sampling and shoreline mapping proceeds, by extending a white raft paddle into the lake on the lee side of the raft. The checks are made at many points around the lake. Middle Fork Snoqualmie River drainage (16 September 1984). G. Ring Erickson photo.

Plate 27. Precise measurements of fish weight can be obtained with light, easily packed spring scales. The blue scale, about 9 inches long, can be read to one gram.

Plate 28. A west slope (Twin Lakes) cutthroat from a small lake in the Pratt River drainage exhibits moderate to heavy internal fat reserves, and a light orange flesh color. (14 August 1991)

Plate 29. A golden trout with light visceral fat deposits has a deep orange to red flesh color, and had been feeding exclusively on large calanoid copepods. The female would have been sexually mature the following spring. (1 August 1984) C. Kraemer photo.

a standardized manner on numerous stunted populations in King and Snohomish Counties to establish baseline conditions. Reduction in fish abundance through biological controls, spawning area blockage, or other means can then be evaluated in terms of improved fish condition, as well as other measures, such as catch per unit effort (see Section 5.7.2).

Fish Diet

Nearly all information on trout or char diets in Washington high lakes is qualitative. Most biologists take field notes on the relative abundance of food organisms seen in fish collected by hook-and-line, or by gill net (Cummins 1972; Williams 1972; Lucas 1989). No information on fish diet was reported by Deleray and Barbee (1992). Most of the biologists maintain notes on diet in individual lake files, or in spreadsheets. Pfeifer has logged all diet information from the field forms (Appendix B) to an electronic database for King and Snohomish County lakes (n=1747). Some biologists (Cummins, Pfeifer) have also noted relative degrees of stomach fullness, but of course this can vary greatly, especially at times of certain insect hatches. Dietary items are typically identified to the lowest taxon identifiable in-hand, which is generally not lower than the Family level.

A common phenomenon observed in Washington high lakes is dietary prey resource partitioning, or fish selectively feeding on one prey item, while other fish feed selectively on another. This is most easily observed in the flesh color when time is not available to make iterative samples of the diet over days or weeks. Fish which are feeding fairly exclusively on crustaceans, most commonly large calanoid copepods such as *Hesperodiaptomus*, or on *Gammarus*, develop a rich orange to red flesh color due to the carotenoid pigments these organisms carry (Andre' 1926; Miki 1991). Trout which are feeding on insects have a characteristic flesh-colored or very pale yellow hue (Plate 31). Flesh color is very highly correlated with stomach contents in trout from Washington high lakes (WDFW file data). (This relationship is not as clear-cut with char such as eastern brook since the lining (peritoneum) of the body cavity has a yellow to light orange tint which somewhat masks the underlying flesh color.)

General Fish Abundance

This is one of the most difficult and challenging pieces of information to obtain from high lakes, especially wilderness lakes. Very few district biologists have the time or resources to perform classic mark-recapture type population estimates such as reported by Nelson (1987) and Gresswell et al. (1997). However, this would be extremely valuable information, if collected in a systematic fashion, and would answer a number of very important management questions. These include:

- Average annual mortality of stocked, single-age fish communities;
- Average annual mortality of moderate to high-density, reproducing fish populations;
- Average annual angling mortality, if linked to creel survey;
- Fry recruitment from varying quantity and quality of spawning habitat area; and
- Calibration of indirect, less-precise measures of abundance, such as the number of fish seen rising or cruising, for which a large amount of data has been collected (Section 5.2.1).

Plate 30. An eastern brook trout from Unnamed Lake in the Skykomish River drainage exhibits very poor condition. July, 1993. J. Ledbetter photo.

Plate 31. The fish on the left (surveyor's right hand) had been feeding on insects, while the other had been feeding on crustaceans. Both fish were caught from the same lake. (September 1979). G. Ring Erickson photo.

Most of the biologists have qualitatively appraised fish abundance based on knowledge of the stocking history, the probability, or knowledge of reproduction, their visual observations at the lakes, and catch per unit effort (cpue) from hook and line (h/l) sampling or set gill nets (Plates 32, 33). Fish abundance has usually been classified as Low, Moderate, or High (Appendix B), along with comments made at the time of the survey. Some biologists have calculated cpue for their h/l sampling and net sets. An overnight set of a standardized gill net has the advantage of being less biased than angling, where angling skill varies among biologists. The small mesh sizes of a set net are also better able to sample small fish than h/l sampling. Pfeifer calculated cpue for both h/l sampling and net sets, and noted both the set/pull times and the period of darkness for two calculations of net set cpue (Appendix B).

Johnston (1999) recommended summarizing reproduction in four general categories (None, Low, Moderate, High) based on the number of small fish (10-150 mm) seen rising or cruising within a standardized amount of time, or along a standardized reach of shoreline. Although this method is largely subjective, it offers a prototype that can be further refined when joined with classic mark-recapture measures of abundance. The reproduction categories would correspond to seeing 0, 1-5, 6-20, or 20-100+ small fish, respectively. The critical management information is a) whether the fish are reproducing or not; and b) to what degree of success. Management biologists need to be able to reliably gauge whether fish density is at or above some threshold level, such as 200 fish/acre. While most of the experienced biologists have developed a "feel" for this level based on surveys of lakes where the number of fish stocked was known, there is a need for a somewhat more quantitative index or measure. Broad application of mark-recapture population estimation is highly unlikely to occur in Washington wilderness areas, or any time soon on the hundreds of lakes where abundance monitoring is an on-going need.

Since sports groups such as the Washington State Hi-Lakers and Trail Blazers, Inc. are the extended eyes of the small agency staff, simple, yet effective indices of fish abundance that are based on observations already made by club members would be of extreme value (see Section 5.2.1).

Evidence of Amphibian Use

Amphibian Life Stages

Most WDFW fishery management biologists have not made directed collections, or extensive visual searches for amphibian adults, larvae, or egg masses as part of their baseline lake surveys. Williams (2001) emphasized that he "never" saw amphibians of any sort in Okanogan County lakes, and opined that they may not have suitable habitat in that part of Washington. Others indicated they were not collecting that type of information, usually because of a lack of time and resources. Some (Cummins, Johnston, Lucas, Pfeifer) have noted their presence in trout diets, or in surveyed lake or pond environments (Johnston 1972, 1973). Beginning in the mid- to late-1980s, Pfeifer routinely made notes on the field lake sketch map of the general abundance of egg masses (almost always *Ambystoma gracile*), larvae seen in the lakes or trout stomachs, and the presence of adult salamanders or newts in the water column (Table 7). Frogs and tadpoles were also noted, and occasionally photographed (Plates 34, 35), but they were not keyed to species. Johnston made similar observations and notes on waters he surveyed in Skagit and Whatcom Counties in the late 1980s and 1990s, but detailed studies on this subject were already on-going in this same geographic area (Liss et al. 1995). (See additional discussion of this key topic in Section 5.6.1.)

There has been little in-depth discussion of, and no agreement on the best methods fishery management biologists should use to survey for amphibians in high lakes managed for fisheries. The local managers are comfortable that if trout numbers are kept low, and stocking is infrequent, there is not apparent impact on amphibians. All evidence to date indicates the current program of cyclic, low-density fry stocking is compatible with native amphibians (Divens et al. 2001). There is no evidence that any amphibian native to Washington's sub-alpine and alpine zones is in danger of extinction at a basin-level scale. Therefore, most local fishery managers, already limited by time and resources, are generally unable to add labor-intensive amphibian surveys to their list of priority information to be collected at high lakes that have not yet received baseline surveys. Additional information on the basin-scale distribution and ecology of salamanders was identified as a high priority research topic in Divens et al. (2001).

Biological data from Washington high lakes are routinely collected by volunteers (Section 5.2.1). Two of the most active of these sport groups have recently solicited training materials and seminars from local experts on amphibian biology and identification. The goal of these anglers is to assist the WDFW in obtaining relevant information on the distribution of amphibians in Washington's high country, and in fish-bearing high lakes. As information is obtained from these volunteers, it will be entered into the HLS database (see Section 5.3.2).

Table 7. Table of Stocking Frequency, Fry Density, and the Occurrence of Northwestern Salamander Egg Masses and the Copepod *Hesperodiaptomus kenai* In A Sample of Surveyed Lakes in King County, 1982-1999 (WDFW Region 4 File Data).

Lake	Elevation (ft msl)	Year First Stocked	Stocking Frequency (yrs)	Fish Reproduction	Stocked Fry Density (number/ac)	Salamander Egg Mass Relative Abundance	*H. kenai* Relative Abundance
Blazer	4060	1929	5	None	87	Mod	Mod
Blethen	3198	1952	4	None	40	Many	Mod
Cougar	4123	1947	9	None	41	Note 1	Mod
Deer	3630	1918	5	Light	50	Low	Scarce
Elbow	3900	1969	0	Mod	0	Note 2	Scarce
Hardscrabble	4800	1947	0	Mod	0	Note 1	Scarce
Hester	4050	1931	6	Low	78	Low	Scarce
Horseshoe	3500	1929	6	None	61	Mod	Low
Isabella	3510	1954	4	None	60	Note 3	Mod - High
Little Kulla	3870	1936	4	None	115	High	High
Olallie	3780	1914	0	High	0	Scarce	Scarce
Pratt	3385	1914	0	High	0	Note 3	Scarce
Little Pratt	4080	1953	6	Low	58	Mod	Low
Thompson	3650	1929	5	Low	64	Note 3	Low
Upper Tuscohatchie	4020	1918	0	Mod	0	Note 3	Mod
Windy	4186	1969	6	None	70	Note 1	High

1. Surveyed in late summer - too late to expect to see egg masses.
2. Surveyed in late summer. Frog tadpoles numerous in shallows.
3. None seen.

Notes on Wildlife Use

Some fishery biologists note the occurrence and activities of wildlife at or near high lakes, in part to assist other WDFW staff, and to document the interactions of wildlife with the artificially-created high lake fishery. These notes have been made to field notebooks, the lake sketch map, or a Comments field on a data form (Appendix B). See Section 5.6.3.

Plate 32. The blue cork line of a 60-ft sinking horizontal gill net can be seen at left center of the photo. Sets are made with the smaller mesh afixed to an object on shore, preferably where there is at least 3 feet of depth at the lake's edge. The net is set perpendicular to shore, avoiding large woody debris on the bottom. Rock Lake, Taylor River drainage (25 August 1993).

Plate 33. With some practice, even 120-ft floating gill nets can be set from a small inflatable raft. (Floating nets must be anchored at their distal end.) The net may be fed into a plastic bag between the surveyor's knees upon retrieval. Unnamed Lake, Skykomish River drainage (27 September 1996). G. Ring Erickson photo.

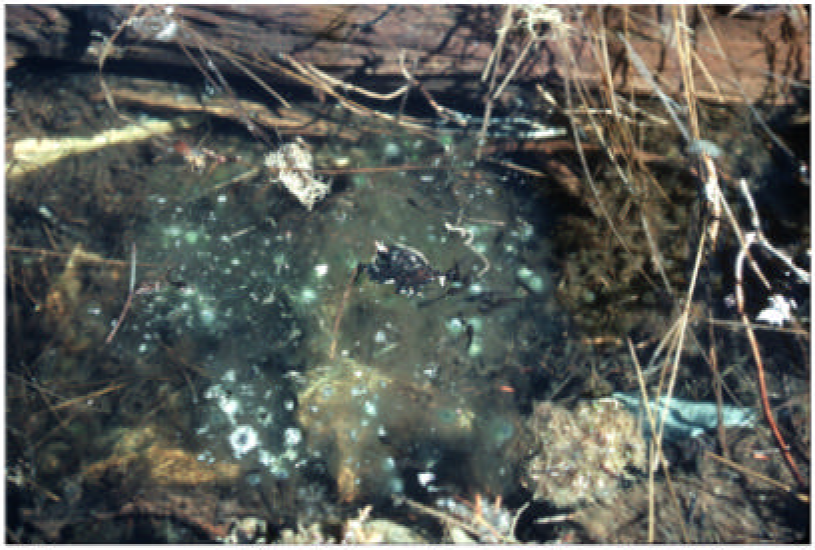


Plate 34. Eggs or egg masses of Cascade frog, northwestern salamander, and other species are commonly seen along the edges of ponds and lakes of all sizes in the west central Cascade Mountains. Egg masses may be at the extreme edge, or in several feet of water, depending on the species. Amphibians coexist with trout in this periodically stocked lake. Upper Snow Lake Pothole, Middle Fork Snoqualmie River drainage. (25 July 1988).

Plate 35. Smaller, shallow tarns such as this one which lies within 100 feet of a larger lake that has a reproducing population of cutthroat often support amphibians. Many hundreds of frog tadpoles were seen between the aquatic grass and the water's edge in this pot near Trico Mountain Lake in the Deception Creek and Skykomish River drainage. (8 September 1996)

5.1.6 Assessment and Recommendations

Extensive personal experience by the primary author has conclusively shown that there is no substitute for a professional-level survey on each high lake and pond being managed. Fortunately, much of this very large task has been accomplished over the past 67 years, especially in the last 30 years. The minimum amount of information should be obtained by a professional biologist, or under his/her close supervision. District biologists lacking at least four years of experience in managing high lakes should not delegate this work, but must obtain their expertise first-hand. The exact nature of the "basic survey" information, and methods used to obtain it, has not been standardized, or agreed-to for the varying geographic districts with high lakes.

Recommendation #1a: The economic benefits of the high lake fishery (Section 4.0) should be borne in mind, and a greater amount of staff time allocated to completing baseline surveys on all districts. There is a particularly acute need for this in Chelan County. A standardized Methodology for completing baseline surveys should be prepared by or with current staff, and be published (internally or externally) for current, and by far most important, future staff use. Summary reports based on these surveys should include the information contained in the samples provided in Appendix C.

Recommendation #1b: Staff agreement should be reached on the types of information, and level of detail obtained in a "baseline", or "Level 1" survey. The data form in Appendix B may serve as an example, or basis for in-depth discussion. Similar definition should be developed for any higher level surveys deemed necessary for management or research purposes.

More complete information on spawning habitat and the current level of fish reproduction is needed for many lakes. This can be considered a subset of the assessment and recommendation above. This information is critical for addressing potential impacts of the program on native invertebrates and amphibians. While much is already known (Table 5), the remaining information gap should be filled as soon as possible.

Recommendation #2a: This recommendation is closely related to #1. If staff time or geographic work areas must be prioritized, new baseline surveys or collection of information on spawning area and fish density should be focused in Chelan and Kittitas Counties.

Recommendation #2b: Mark-recapture population estimates should be made in a carefully-chosen set of lakes in an attempt to calibrate commonly-used indirect measures of fish abundance (numbers seen rising, cruising, etc.). Counts of fish obtained by snorkeling shoreline reaches should be a part of this evaluation. A related question is whether cpue reported by high lake volunteers is correlated with actual fish abundance (Richards and Schnute 1986).

There is usually little need for physical and chemical data to make routine management decisions on high lakes with long management histories, apart from surface area. However, two major benefits could come from analysis of existing data for the purpose of developing a model of the relationship between habitat variables and trout growth in Cascades and Olympics high lakes:

- Existing and future fishery managers (in Washington and elsewhere) would gain an increased understanding of the relationships between sub-alpine and alpine aquatic habitat in this ecoregion, and trout growth rates. Since the model/s would be developed from lakes where trout densities are known, and controlled through stocking, the information would lend much scientific credibility to the current WDFW assertion that low density stocking not only leads to quality trout, but is ecologically compatible with the natural aquatic environment.

- Trial and error over many years has established appropriate stocking rates and frequencies for most lakes under active management. The greatest benefit of a model to managers would be for the setting of stocking levels for lakes that are either currently barren, or that have had all of their fish removed. (Habitat assessment and re-stocking should occur after a period of recovery for the invertebrate community in cases where a chemical treatment is used.)

Recommendation #3: Existing data collected by Johnston and Pfeifer from lakes in Clallam, Jefferson, Mason, Whatcom, Skagit, Snohomish, and King Counties should be analyzed with the objective of developing one or more models of trout growth in relation to habitat variables in Olympics and Cascades high lakes. Preliminary analysis of a subset of this data by Johnston suggests the model/s would consist of a relatively low number of easily-measured parameters.

There has been much speculation of, but little proof of the impacts of low-level trout stocking on native amphibians in Washington. Given the high demand for quality trout fishing in Washington (WDFW 1996a), and the great cost-effectiveness of the high lake trout program (Section 4.0), efforts should be made to address questions that remain.

Recommendation #4: The prioritized research studies listed at the end of Divens et al. (2001) should be methodically implemented. They should occur in the sequence noted, since information obtained from the higher-priority topics may obviate the need for some of the lower-priority ones.

5.2 FISHERY MONITORING

For the purposes of this report, monitoring is taken to mean the periodic or annual collection of information on trout growth rates, angler use, angler catch success, quality of fishing (angler satisfaction), and environmental impacts at lakes for which a fishery has been established. Monitoring typically occurs on lakes which have long histories of fish presence and angler use, but also includes waters that are visited by only a few individuals annually. It does not include the data collection required to catalogue the existing habitat and fish population conditions when a "baseline" survey is first completed. (There are still numerous fish-bearing high lakes in Washington that have not yet received a baseline survey.)

5.2.1 Professional and Volunteered Survey Reports

WDFW Monitoring

Most WDFW district fish biologists perform monitoring, or "follow-up" surveys on some of their lakes each year. The number surveyed varies substantially among the districts, due to varying demands of other programs during the summer and fall. A goal of 10 to 15 lakes per year has been established for each region. Some biologists with high anadromous fish time demands and few high lakes may survey two or three lakes annually; others with hundreds of high lakes on their district and less competing demands on their time have surveyed as many as 20 to 25 annually.

Some biologists use the form found in Appendix B, or a close facsimile. Some simply log notes to a waterproof notebook. However, the form in Appendix B is intended for baseline surveys. The type of data collected for routine monitoring is much closer to that requested on the revised High Lake Fishing Report Form (Appendix D). Key information includes the survival of the previous fish introduction (relative abundance and catch rates), fish growth and condition, evidence of reproduction, the number of anglers and other users at the lake, use/campsite impacts, and access conditions.

Monitoring by Volunteers

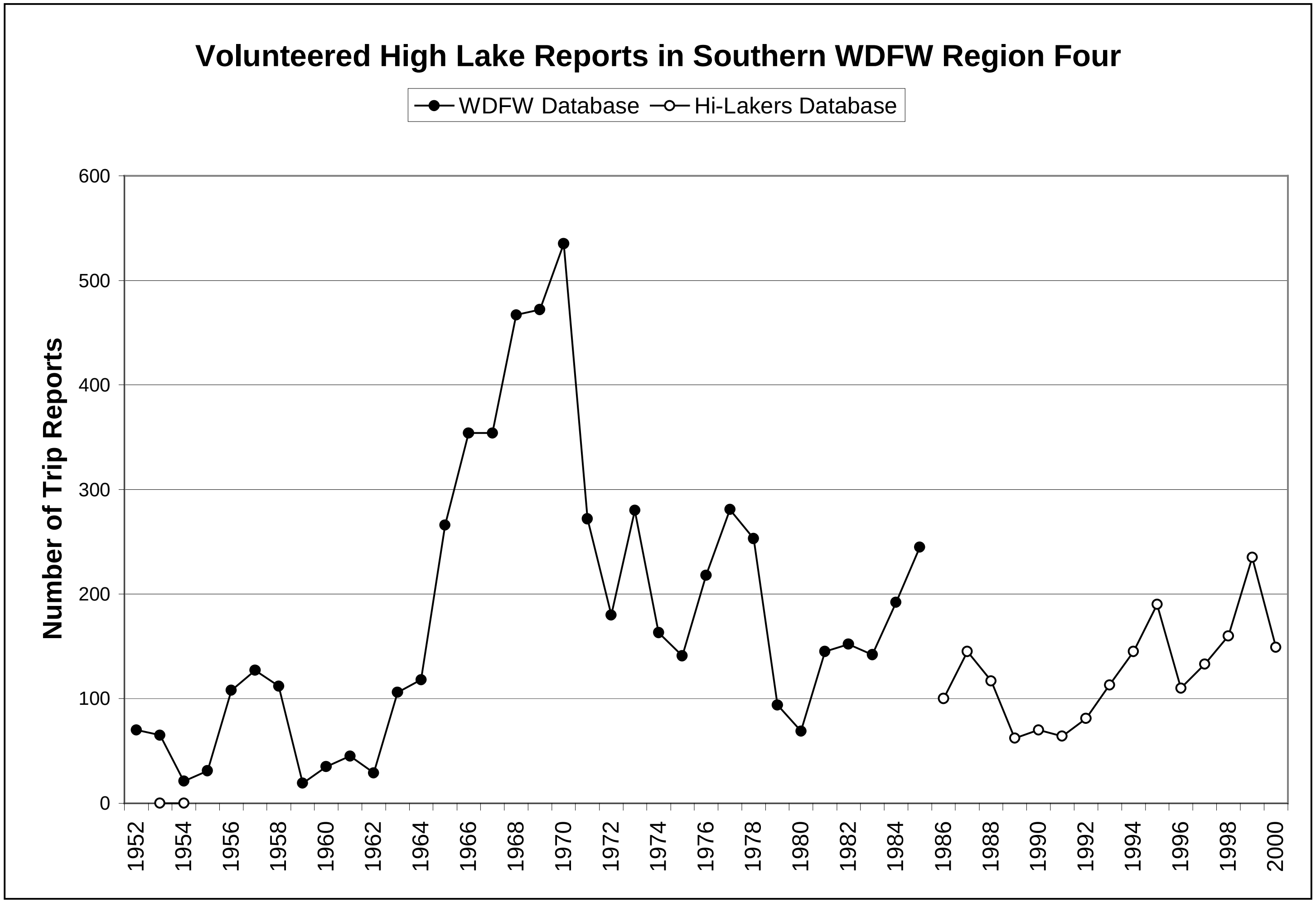
A unique high lake fishery monitoring situation may exist in the State of Washington. While the use of angler diaries by fishery managers is not new (Anderson and Thompson 1991), very few volunteered creel data programs date back to the mid-1950s, especially for remote high lake fisheries. As described in Section 2.0, High Lake Fishing Report cards were instituted in Washington in about 1955. The Washington Department of Game distributed thousands of the cards through regional offices and Forest Service district offices, and many hundreds were returned. The cards were promoted in Washington Wildlife magazine, on radio spots, and in mailings to sports clubs. However, returns of the cards dropped continuously in the late 1970s and early 1980s for reasons that are now obscure.

The old WDG High Lake Report card was revised and updated in late 1985, and was first used in 1986 (Appendix D). This form has almost completely supplanted the earlier form, particularly in WDFW Region Four. The use of this form was promoted with the Washington State Hi-Lakers and Trail Blazers, Inc., the two major high-lake oriented fishing clubs in Washington, both located in Seattle. Walt and Brian Curtis of the Washington State Hi-Lakers were particularly instrumental in developing the revised form with WDFW district fishery biologist Bob Pfeifer. The form was revised to allow entry of all contributed information into an electronic database.

Figure 9 shows the number of angler reports received for southern Snohomish County, and all of King County since 1952. Reports received through 1985 were obtained primarily by public distribution and publication of the original WDG-designed High Lake Report Card. An annual peak of around 500 trip reports obtained by use of this card occurred in 1971. The number of reports then quickly dropped, and varied between 150 and 250 reports per year through 1985. In recent years the number of trip reports received with the new form has similarly ranged from 110 to 235, and has averaged about 154 since 1993 for this district

.

Figure 9. Volunteered high lake angler trip reports submitted for lakes in southern Snohomish County, and in King County, 1952-2000.



Since the mid-1970s WDFW district fishery biologists have provided the Washington State Hi-Lakers and Trail Blazers, Inc. annually updated lists of high lakes that they would like surveyed. In about 1998, the Washington State Hi-Lakers initiated a more rigorous survey program. While stocking of the high lakes is the principal objective of the Trail Blazers (Yadon et al. 1993), the Washington State Hi-Lakers made lake surveys their principal objective.

WDFW management biologists meet or communicate with these clubs at least annually to discuss and coordinate the list of lakes to be surveyed in the upcoming year. The lake list will often specify the types of information sought from individual lakes, such as survival of previous introductions, or the presence of natural reproduction. Presentations to the club/s by biologists help assure that information obtained is accurate. Programs have been presented on amphibian life stage identification, as well as ways to gather data on trout age, growth, diet, and condition. Reports received from the club members are compiled, and a data summary is provided to the individual WDFW management biologists a few months after each hiking season.

While the Trail Blazers and Hi-Lakers contribute many trip reports to management biologists in several WDFW administrative regions (Table 8 and Figure 10), their number of trips and annual report submittals naturally diminish in more or less direct proportion to the trailhead distance from the Seattle area (Appendix I). Nevertheless, the groups do perform surveys in all areas of the Cascades, and to a limited degree in the Olympics. Management biologists in other districts have established feedback relationships with other groups such as the Backcountry Horsemen, or key local anglers, but none of these rival the scope or effectiveness of the program based in Seattle, which has been growing steadily (Figure 11).

Table 8. The Number of High Lake Fishing Reports Submitted to WDFW by Administrative Region, 1986 through 2000.

WDFW Region	Hi-Lakers Reports	Trail Blazers Reports	Total Reports[1]
2	594	134	681
3	529	185	640
4	2028	1002	2487
5	134	48	154
6	137	37	160

1 The total does not equal the sum of the two clubs since numerous individuals are members of both clubs.

Figure 10. The Number of High Lake Fishing Reports Submitted to WDFW by Year and WDFW Administrative Region, 1986 to 2000

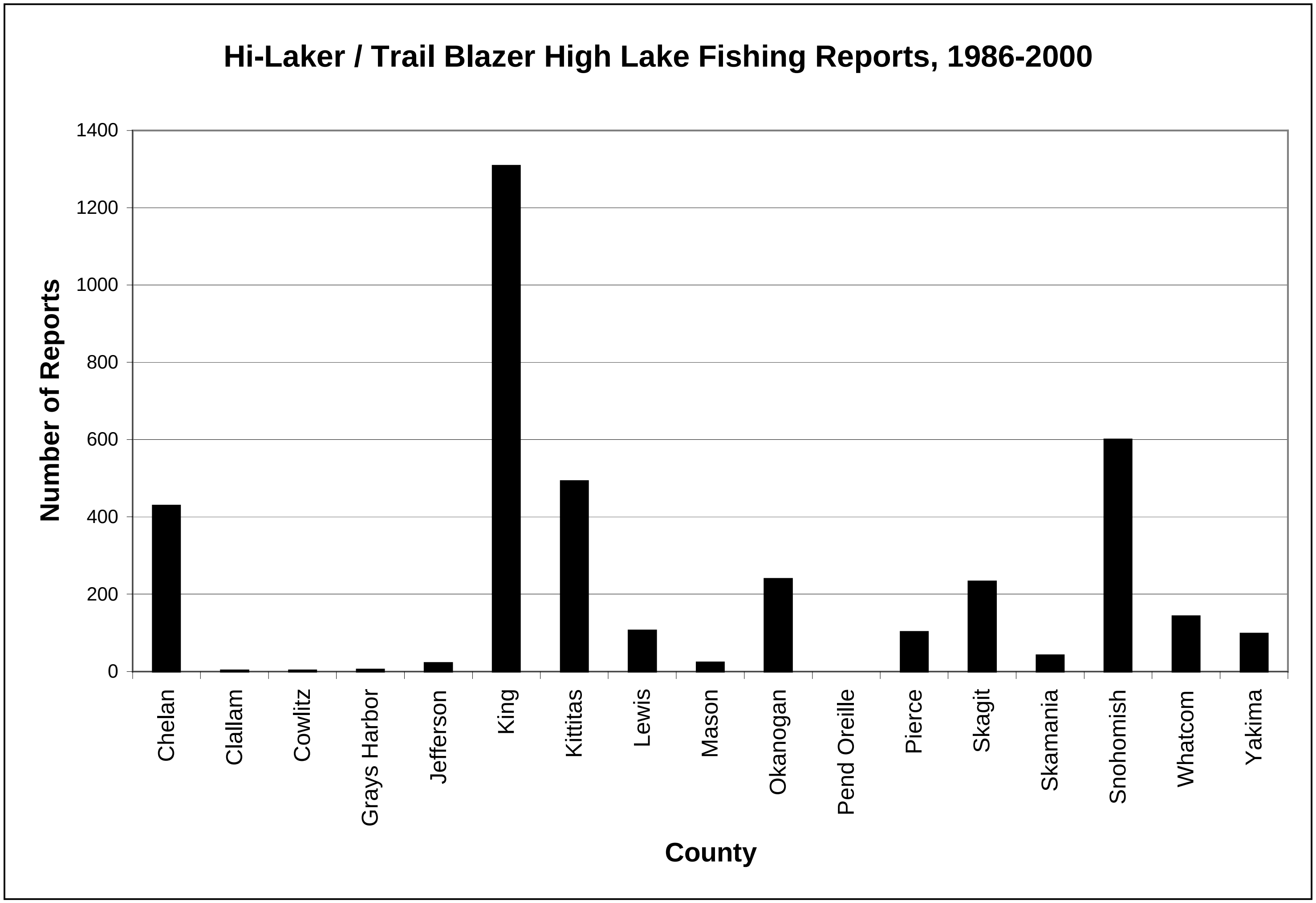
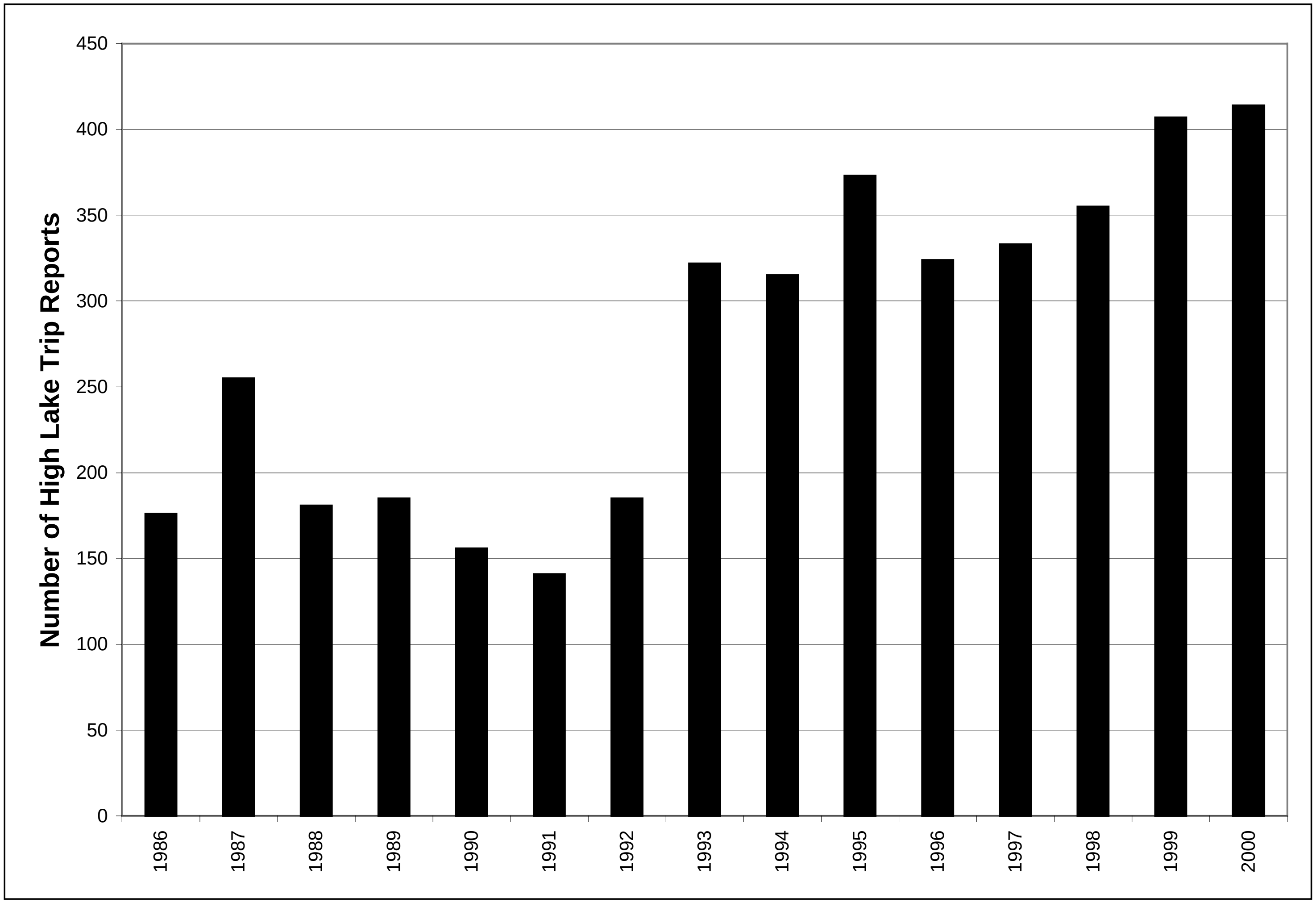


Figure 11. The number of High Lake Fishing Reports entered into the Washington State Hi-Lakers database by year, 1986-2000.



The statistical problems of creel survey in general (Carlander et al. 1958; Radford 1973), and volunteered information (Tarrant et al. 1993; Fisher 1996) are recognized. However, WDFW fish biologists have held recurring training sessions with members of the Trail Blazers and Hi-Lakers. The most active surveyors have many years of experience in the high country, and understand the data needs of the agency. This tends to minimize, but does not eliminate problems with data quality. Data collection biases associated with particular surveyors are also recognized by biologists who have long professional and social relationships with many of the surveyors. There is no substitute for the "filtering" function an experienced manager must perform with this type of data. This quality control can only be fully developed through experience, but a detailed description of the procedures and potential statistical pitfalls should be written. Despite the shortcomings, surveys performed by volunteers greatly increase the amount of information that can be collected for managers who have up to 600 high lakes on their districts.

The most valuable and reliable feedback provided by volunteered surveys include:

- Current access conditions; road closures, locked gates, trail washouts, access policy changes, etc.
- Presence of fish; success of preceding fry introductions.
- Size ranges of fish caught, and general fish condition.
- Number of other anglers and non-anglers at the lake/s during the survey.
- Number of, and condition of campsites.
- Verification of natural reproduction, if fry are noted that do not jibe with stocking record.
- Date of iceout.
- Observations of dead fish.
- Use of fish by other forms of wildlife.

Other valuable information, but less reliable, and needing strict quality control by the local management biologist, includes:

- Catch rates for fish present, by species.
- Relative abundance of fish.
- Absence of fish.
- Fish stomach contents.
- Presence of salamanders, by species.
- Presence of conspicuous zooplankton or macroinvertebrates.

A sample of the type and quantity of information available from the database of High Lake Fishing Reports is provided in Table 9. Close to 4000 trip reports have been logged since 1986. The data show that the party size of the type of high lake anglers found in the two Seattle clubs is generally one or two individuals, and that usually less than one other angler is present at the lakes visited. This is largely due to the fact that lakes for which a survey has been requested, or that these avid high lake anglers visit, tend to be small and remote. Selective queries of the database would yield much different information on larger, more popular lakes.

Table 9. Summary Statistics by County From Volunteered High Lake Fishing Trip Reports (Washington State Hi-Lakers and Trail Blazers, Inc. databases)[1].

County	No. of Lakes Surveyed[2]	Reports Submitted[3] Since 1986	Mean No. of Anglers in Party	Mean No. of Other Anglers at Lake	Mean Number of Hours Fished	Number of Reports Where Fish Caught	Percent of Trips Where Some Fish Caught
Chelan	164	429	2.0	0.9	1.3	253	59.0
Clallam	3	3	1.0	1.0	0.7	1	33.3
Cowlitz	3	3	1.0	0.0	0.8	0	0.0
Grays Harbor	3	5	1.7	0.4	1.7	4	80.0
Jefferson	15	22	1.6	0.0	0.9	14	63.6
King	303	1308	2.1	0.8	1.6	631	48.2
Kittitas	98	492	1.7	0.4	1.1	215	43.7
Lewis	51	106	1.8	0.4	1.1	42	39.6
Mason	12	23	1.7	0.4	1.2	14	60.9
Okanogan	118	239	1.9	1.8	1.5	137	57.3
Pend Oreille	0	0					
Pierce	56	102	1.9	0.7	1.0	39	38.2
Skagit	92	233	2.2	0.5	1.6	125	53.6
Skamania	29	42	1.8	0.2	1.1	16	38.1
Snohomish	163	600	1.9	0.6	1.6	273	45.5
Whatcom	62	143	1.8	0.3	1.4	69	48.3
Yakima	50	98	1.8	0.4	1.2	49	50.0
Total or Mean	1222	3848	1.74	0.56	1.23	1882	47.5

[1] There are numerous other data categories which are not shown in this table.

[2] The number of unique lakes in the county for which there is at least one volunteered trip report.

[3] The total number of trip reports for all lakes, including repeat reports on individual lakes.

Not all trip reports logged into WDFW district fish biologist databases or lake files are provided by organized sports club members. Numerous reports are annotated from unsolicited calls made by interested anglers to the local biologist. Relevant information (usually on non-fish related issues such as access) have been gleaned from chat group or trip report postings on web sites maintained by groups such as the Washington Trails Association (http://www.wta.org/scripts/wta/cgi-pvt/web9.pl?tr+fr+date) or Washingtonlakes.com (http://www.washingtonlakes.com). The popularity of these web sites suggests the Internet may be an effective way to solicit input from a larger segment of the high lake fishing public.

5.2.2 Assessment and Recommendations

Most of the local fishery managers are pleased with the quality and quantity of angler-based feedback they receive. Annual development by the biologists of lists of lakes to be surveyed results in the highest quality of feedback, given the limitations inherent in volunteer-based data collection. In the past few years, competing program demands have prevented some district biologists from preparing updated lists of lakes to be surveyed, which has diminished the effectiveness of the process.

Recommendation #1: Given the high overall value of the high lake fishery (Section 4.0), a greater amount of staff time should be allocated to restore full coordination with volunteers and organized sports groups on high lake fishery monitoring.

Recommendation #2: As staff time and resources allow, use of the Internet or the agency web site should be explored as a means to augment the volunteered information obtained from organized sports groups.

Recommendation #3: The Trail Blazers, Inc. and Washington State Hi-Lakers databases should be considered a resource to draw upon by WDFW fishery managers, even if on a contractual basis. This report has only touched upon the potential value of the statistical information contained within them.

Recommendation #4: The High Lake Fishing Report form (Appendix D) should be the basic form used to collect information from volunteers. It can be easily modified as needed for special purposes. Information from the form is logged to a database, which can be queried for various reports. Summary information can be readily prepared for inclusion in individual lake management summaries (Appendix C).

5.3 DATA MANAGEMENT

5.3.1 Stocking History

Purpose

There are several reasons to prepare an accurate and complete stocking record for the high lakes of each district. These include:

- Knowledge of past species and strain introductions to determine application of the Exotic Species Policy when “new” introductions are contemplated;

- To enable interpretation of differences in species and stock (strain) performance in individual lakes, or regionally;

- To be able to map the previous, or current distribution of species or strains across the landscape (Williams 1999), and interpret genetic information from wild fish in receiving waters;

- If historic “hard” agency records are lost or destroyed, they are often irreplaceable.

Historic and Existing Conditions

Records of fish introductions into lowland and high lakes between 1933 and the mid- to late 1990s were maintained in both regional and headquarters offices of the Washington Department of Game (WDG; later WDW, then WDFW). The majority of the records were hand-logged or typed onto a standardized “Record of Planting” card (Appendix E). Broad use of this card did not begin until the mid-1950s. Introductions made prior to about 1955 (for both high and low waters) were recorded on hatchery stocking sheets and other media, and were not always transferred to the new cards. Most of these early, pre-1955 records were archived in one or more locations in the WDG Olympia headquarters, or in regional offices.

Miscellaneous (far from complete) records of stocking performed by the various counties, as well as by the U.S. Forest Service, were deposited in individual lake files in the WDG headquarters warehouse.

Some WDFW fish biologists accessed these historical records (Pfeifer, Johnston) and incorporated them into the regional/district stocking databases. Other documentation, although somewhat less reliable by being unofficial, occurred in sportsmen's guides such as Piper & Taft, Inc. (1925). In at least one instance, these non-WDFW historical stocking records proved to be invaluable in explaining the "appearance" of a fish species not seen in a high lake in King County in many decades (see Section 5.7.2).

Concurrent stocking records were maintained by the Trail Blazers, Inc., based in Seattle. These consisted of introductions made by the club, as well as stocking performed by the WDG. They included trout stocked into lowland lakes, ponds, and streams as well as high lakes and ponds. Paper records, largely in the form of letter correspondence and copies of agency fry allotments and stocking summaries, were later converted to electronic databases by Mike Swayne, Trail Blazer Librarian.

The current WDFW stocking data recording procedure is a 5-step process beginning with preparation of a stocking allotment by the local fishery management biologist:

1) District fish biologists prepare their annual allotment for high lakes (or lowland waters) on their district.

2) Regional fish biologists combine the requests of all local biologists into a regional allotment, which is routed to the agency headquarters for approval.

3) When approved, allotments are forwarded to the affected hatcheries, whose staffs conduct the actual stocking. (Local biologists or volunteers may or may not assist in the stocking process. However, Trail Blazer implementation of much of the high lake stocking has occurred since 1933. See Section 5.4.5.)

4) As stocking is accomplished, monthly hatchery reports are distributed to the regional and/or headquarters offices. Introductions are entered into the headquarters databases as they occur, i.e., when monthly stocking reports are received. Regional office staff processes may vary; some regional staff elect to maintain their own local databases, and either enter stocking data as they receive it from the hatcheries, similar to the central database, or accumulate the information, and enter it at the end of the stocking season. (With respect to the high lake program, this latter approach has important quality control implications. See Section 5.4.5.)

5) Regional offices have an opportunity to perform a quality control check on the central stocking database when an annual summary of the previous year's introductions is mailed or emailed to the regional staffs for review. Not all regional biological staff apply rigorous quality control to the stocking data submitted by the hatcheries, but base their management decisions on previous allotments.

An important step affecting this process, but not strictly related to the management of high lake stocking data, is the preparation of egg allotments by the local fishery biologists roughly one year in advance of the actual stocking season. Biologists project their probable fry stocking needs about a year in advance so hatchery staffs can plan on collection of spawn from captive broodstock, or from semi-wild populations in broodstock lakes (see Section 5.5.3). This step would occur just before #1, above. Hard copies of egg allotments have been maintained in agency files, similar to fry allotments and stocking records.

5.3.1.1 *Historical Accuracy*

Some of the current and recently-retired WDFW district fishery biologists (Appendix A, Table 1) have taken pains to perform quality control on the historic stocking records for their districts (Parametrix 2001). The number of previous years where biologists feel they have successfully reconstructed the stocking history, or where they feel errors have been corrected, varies among the districts. Bob Pfeifer and Jim Johnston did a thorough review on the available information for high lakes in King, Snohomish, Skagit, and Whatcom Counties, and feel they may have successfully reconstructed the record of official high lake introductions back to 1933 and agency founding. Larry Brown also made a concerted effort to assemble a complete and accurate record for Chelan and Kittitas County high lakes. Ken Williams felt he had successfully reconstructed the record for Okanogan County lakes back to about 1966. Prior to that WDG Game Warden Dick Chandler and USFS employee Francis Lufkin had "stocked large numbers of fry" beginning in about 1961, but records of these introductions were unavailable (Parametrix 2001). It may be assumed that current records prior to the mid-1950s for other counties are incomplete, and to some unknown degree, inaccurate. No rigorous, standardized quality control process has been applied statewide to all high lake stocking records.

Bob Pfeifer found in his effort to minimize errors and omissions in the stocking record for King and Snohomish Counties that comparison of several sources of information was essential to identify errors. In a very small percentage of the overall individual stocking events, inconsistencies could not be resolved. (These were typically which unnamed pothole among a group of proximal pots was stocked, not whether a stocking event occurred.) The information sources included:

- Trail Blazer stocking histories and hard copies of records of their own, plus WDG;
- WDG/WDW/WDFW stocking allotments;
- WDG/WDW/WDFW hatchery stocking records;
- WDG/WDW/WDFW "Record of Planting" cards;
- WDG stocking data summaries for individual lakes or counties, located in regional and headquarters files; and
- Corroborating, but unofficial information in published angler guidebooks.

A general problem with the historic stocking database, even into the 1980s, was failure to note the strain, or sub-species of fish stocked (e.g., listing "cutthroat" and not noting 'Twin Lakes' or 'westslope', or 'Tokul Creek' (coastal)). However, in many cases the strain stocked could be inferred by the size of the fry and date of the release, where intimate knowledge is known of the production characteristics of individual hatcheries (e.g., coastal versus westslope cutthroat from the Tokul Creek Hatchery).

5.3.1.2 *Central and Regional Databases*

Central

All statewide inland fish stocking records back to about 1981 have been entered into a Unix-based Paradox database in WDFW's Olympia headquarters. New stocking information is entered into the database on a monthly basis as the hatcheries submit their stocking summaries at the end of the month. High lake stocking generally begins in June, and ends in October, although some unusual introductions have occurred as late as mid-December. Most high lake stocking data entry occurs from June through November.

Regional

High lake stocking data management varies among the regional offices. Some district biologists maintain records in databases or spreadsheets on their office PCs. Some regions continue to update the "Record of Planting" cards. A general problem is lack of a consistent, standardized approach to management of these data among the regions, and between the regions and agency headquarters. Some regions rely on the Hatchery Program (which dispenses the fish to volunteers and sponsors) to follow the allotments, and to track and make an accurate accounting of what gets stocked. This is then recorded in the central database, an updated electronic copy of which is annually sent to the regions for review. Other regions check stocking data accuracy earlier in the process by reviewing hatchery stocking sheets which are submitted to the central database.

Database Coordination

Most of the biologists polled in Wenatchee (Parametrix 2001) stated they had data inconsistency problems between their local records, and those logged to the central database. While the inconsistencies are not large (affecting many records, or involving large value errors), they are chronic. Most relate to problems of identification of the specific lake or pond actually stocked. This problem is almost always limited to small, unnamed lakes or potholes where a location descriptor such as a quarter Section is insufficiently precise to eliminate confusion with a nearby water body. The second most frequent problem is confusion over the name of a stocked water.

Both of these problems can be corrected by local fishery managers if they review the hatchery stocking sheets. Headquarters data entry staff do not have the intimate knowledge of the lakes, or the regional fry stocking allotments, to catch errors of naming or location that occasionally occur on the monthly hatchery stocking summary. These data entry errors can be caught and corrected when the annual stocking summary is mailed to the regions for review. An alternative approach would be for the local fishery managers to enter the stocking data into the central database. They have the best ability to identify errors in the data, particularly for high lakes. These problems are far less significant for lowland lakes and streams for which legal descriptions of stocking locations are generally adequate to prevent any confusion as to which water or stream reach was actually stocked.

An additional quality control check on high lake stocking data occurs when volunteers, notably Trail Blazers, notify the agency of the number of fry that were lost in transit, or during the stocking process. This results in small, but occasionally significant differences in the number of fry reported by the hatchery as having been "stocked", based on what left the hatchery, and what should be entered into the formal database. Most regions have set up procedures so that the number of fry lost in transit is deducted before the monthly hatchery stocking summary is submitted. Again, there are exceptions to this, and continual diligence by the local fishery manager, in coordination with any volunteers, is required to maintain the highest level of data quality. This has been a regular process with the Trail Blazer program since at least 1978.

5.3.2 Fishery Reports Databases

Volunteered angler trip reports have been submitted on High Lake Report Cards, and its updated version (Appendix D; see Section 5.2.1). Most biologists have retained the old cards in metal or manila files, and continue to access them from those repositories. The newer report form is distributed by the Washington State Hi-Lakers to the district fishery biologists either as single sheets as submitted by the reporting individual/s, or more recently, in a summary, stapled hard copy printout form. At this point local managers either separate the forms and file them in the relevant individual lake files, or convert the hard copies into electronic records.

Bob Pfeifer built upon a dBASE framework originally developed by Larry Brown in the mid-1980s (Appendix Table 1) to produce a concise summary output of all relevant management information for individual lakes in King County and portions of Snohomish County (Appendix F). This has been accomplished for about 600 waters in that geographic area, although only about 390 of these waters are actively managed for a fishery. This has the great advantage of presenting the historic, as well as the most recent trip report (monitoring) information alongside the stocking history and management prescription for each lake. This relational database system is the most efficient and valuable way local managers can utilize the continually evolving and growing information base on each managed water.

5.3.3 Management of Inventory Data, Cataloguing Data, & Permanent Files

All of the local WDFW high lake management biologists retain the original field data forms, lake sketch maps, and notebooks from baseline surveys in manila files and/or 3-ring notebooks. A few biologists (Larry Brown, Bob Pfeifer) have converted much of the field data to electronic databases (dBASE), although the original field notes have been retained. Several (Bob Lucas, Bob Pfeifer, Jim Johnston) have developed lake by lake summaries, or management plans (Appendix C) in electronic word processed files (PC-Write, Word Perfect, MS-Word). These files tend to be more complete than recent technical reports (Deleray and Barbee 1992), but are similar in many ways to the seminal works published in the early 1970s (e.g., Cummins 1973; Johnston 1973). This approach is most complete for high lakes in King, Snohomish, Skagit, and Whatcom Counties (1,514 waters), but has not been published in the form of the earlier technical reports. The degree to which these summary files, or lake by lake management plans have been completed varies from region to region (Table 10). Most of the other biologists are using spreadsheets to catalogue lake by lake data and brief management recommendations (Parametrix 2001).

Electronic files of basic field data and the lake by lake management plans have been backed up and stored in a safe deposit box for King and Snohomish County waters. Similar electronic files from other districts should receive similar care.

An electronic file listing the lakes defined as high lakes and used as the source for several figures and tables in this report is included as Appendix N. This file was assembled from several sources and includes lake names, identifications, sizes, elevations and locations. The file also includes a cross reference between various lake identifiers that have been used.

Table 10. Percent of Managed[1] Washington High Lakes (Exclusive of Olympic and Mt. Rainier National Parks and Yakama Indian Nation) for Which a Summary File or Management Plan[2] Has Been Developed as of 2001.

County	Number of Managed High Lakes	Number with Summary File or Management Plan (Percent)
Jefferson	38	38 (100)
Grays Harbor	6	6 (100)
Mason	24	24 (100)
Whatcom, Skagit, No. Snohomish	187	103 (55)
Southern Snohomish	143	80 (56)
King	532	532 (100)
Pierce	98	32 (33)
Cowlitz	11	11 (100)
Lewis	136	136 (100)
Skamania	254	254 (100)
Yakima	154	154 (100)
Kittitas	167	167 (100)
Chelan	302	217 (72)
Okanogan	240	108 (45)
Pend Oreille	15	15 (100)

1 "Managed" means a decision has been made to maintain the water as fishless or with a fish population, whether or not a complete "baseline" survey has been made.

2 "Plan" as used in this table consists of one or more surveys, and some sort of management prescription or recommendations (see Appendix C). Many local high lake management plans are not yet at the level or in the format set out as a goal by Fish Program leadership in the mid-1990s.

5.3.4 Assessment and Recommendations

Not all district fishery managers have done a thorough quality control check on their historic high lake stocking data. Counties in which a fairly complete check or reconstruction has occurred (e.g., back to 1955 or earlier) include Cowlitz, Lewis, King, Snohomish, Skagit, Whatcom, and Chelan Counties. Those for which data back to the late 1960s have been reviewed include Clallam, Jefferson, Mason, Pierce, and Okanogan Counties.

> **Recommendation #1:** Temporary, student, or intern help should be obtained to complete reconstruction and quality control checks on the historic high lake stocking data in those counties for which it has not been completed. A one or two-page summary memo should be prepared giving an evaluation of the completeness and accuracy of the task, by region, and be made part of the permanent regional files (or part of an annual report).

Some confusion and lack of consistency still exists in the management of stocking information between regions, and between the regions and the central office. Example: the steps taken to document the number of fry that actually leave a hatchery and are stocked into a high lake (accounting for losses) differs between WDFW Region 3 and Region 4.

> **Recommendation #2:** A workshop should be held between headquarters database managers and selected regional fishery managers. A consistent approach to the handling of stocking data should be agreed upon, from the preparation of allotments to the logging of final, end-of-season fry introduction

numbers. Lakes should be identified at each step in the process by the code used in a central data management system. Simply identifying a lake by county and name or in the case of small ponds by Township, Range and Section often leads to confusion. The initial quality control screen of the hatchery stocking reports should be done by the district fishery management biologist. This could be facilitated and enhanced by their having the ability to query, enter, and edit the central stocking database.

Use of volunteered angler reports by management biologists varies considerably among the districts. For biologists with a small number of lakes and low numbers of monitoring reports, their management is not a significant issue. For biologists with hundreds of high lakes with managed fisheries, and who garner dozens of monitoring reports annually, a standardized report management system would be valuable.

Recommendation #3: A report management system should be agreed upon for those districts that have large numbers of historic reports, or which receive significant numbers of new reports annually. Staff time, or temporary help should be made available to develop this capability, and to train local fishery managers in its use. It should be built upon the model originally developed by Larry Brown for this expressed purpose, or a close facsimile.

5.4 STOCKING CONSIDERATIONS

The following section describes the managerial, biological, and logistical considerations that WDFW district fishery biologists assess when making first-time, or annual decisions to stock high lakes in Washington.

5.4.1 Assessment of Existing Trout Reproduction

Contrary to published misinformation (Bahls 1992), WDFW management biologists are unanimous in stating that the presence of existing reproduction is their foremost consideration in deciding whether to stock their high lakes (Parametrix 2001). The manner in which reproduction is assessed is described in Section 5.1.5. Most lakes under long term management have had an assessment of fish reproduction made (Table 5), but there are significant data gaps, such as in Chelan County.

A more subtle determination is whether natural reproduction is sufficient to maintain a quality fishery, or whether it is excessive, and harmful to invertebrates or amphibians. Fewer of the managers have developed this level of understanding of their lakes and fish populations. Managers who have made first-pass assessment of the <u>level</u> of reproduction in most of their current or previously-managed waters include Anderson and Cummins, Johnston, Pfeifer, and Williams. Most of the other managers have developed a “feel” for this through many years of stocking trial and error, including that of their predecessor managers, coupled with fishery monitoring. Most of the managers have lakes with low-level reproduction which they supplement at low levels on a periodic basis. No manager knowingly adds fish on top of populations of stunted trout or char.

Some district managers have adopted a strict “policy” of not stocking any lake for which reliable information on reproduction was unavailable. (In the case of King and Snohomish County high lakes, a delayed stocking decision primarily occurred for lakes on a cyclical stocking program that were “due”, but for which a reproduction assessment was lacking. These lakes were the first to receive baseline, or Level 1 surveys, prioritized on the basis of ease of access, and potential or documented ability to provide a fishery. In a very few cases, mostly in the mid- to late 1980s, truly new, first-time fish introductions were made, but only after a thorough baseline survey had occurred.).

5.4.2 Stocking Frequency and Density

5.4.2.1 *Frequency and Density*

Although these are two of the most important aspects of high lake fisheries management, there has been relatively little rigorous research in Washington on the underlying factors which determine them, such as natural and angling mortality of trout in high lakes, or angling effort (trips or cumulative hours spent fishing). This lack of detailed investigation is due to factors such as lake access difficulties, low agency staff resources, and dispersed angling recreation, particularly in remote wilderness lakes.

Very limited research-based information on natural and angling mortality of trout in high lakes has been developed, particularly in Washington. In his study of Olympic National Forest lakes in Washington, Johnston (1973) assumed a 10% annual natural mortality rate, and constructed a matrix to estimate trout production to Ages I through V at three different angling mortality rates. Lucas (1989) developed similar trout production tables for lakes in Cowlitz and Lewis Counties, but he assumed higher angler mortality rates than Johnston (1973). This is reasonable, since many of the lakes in Lucas' district are more accessible than the lakes in Johnston's (1973) study area. Working in Colorado between 1967 and 1987, Nelson (1987) calculated annual mortality rates ranging from 40 to 60% for rainbow in Lower Agnes Lake over nine survey years, and 58 to 79% in Summit Lake over four survey years. Nelson also found that brown trout (*Salmo trutta*) had much lower mortality (25%). Nelson's mortality estimates were calculated from gill net catch curves, and therefore are the sum of both natural and angling mortality.

Apart from accepting the stocking rates and frequencies proposed by Johnston's (1972, 1973) initial estimates of trout survival and production in Washington high lakes, most local WDFW biologists have had to use professional judgment, and trial-and-error in establishing stocking rates and frequencies on their lakes. This approach suffers from several limitations:

- Assumed trout mortality rates in broad regional models are insensitive to variability between lakes, or between years; and
- Assumed angler effort and catch success levels are insensitive to changes in access, either between years for individual lakes, or among groups of lakes with naturally varying access difficulty.

There may be no practical way to monitor angler effort with sufficient precision to make small adjustments in stocking rates or frequency to account for rises and falls in angling mortality. The best approach is to obtain some good estimates of natural and angling mortality from lakes that fall into ranges of productivity and angler use, and make general application of the results. Marked fish studies with annual sampling to develop catch curves on fish of known age for the purpose of estimating annual mortality have not been accomplished in Washington.

Lucas (1989) built upon the approach originally suggested by Johnston (1973), and developed a series of production models for varying levels of angling pressure. He recommended choosing the model that best fit the angling pressure and potential lake productivity conditions.

Despite the lack of detailed studies on mortality and angling effort, the average length of time between re-stocking of Washington high lakes has increased substantially since 1970, while the number of fish stocked per surface acre has dropped as well (Figure 4). The statistics plotted in Figure 4 are for lakes that have very little or no natural reproduction occurring in the trout or char populations. Lakes in the latter category are usually not stocked at all. Most biologists endeavor to match stocking frequency and fish density with some assessment of angling effort, so as to provide a reasonable expectation of catch success on quality trout, while allowing the fish populations to dwindle to a low level before re-stocking. The vast majority of lakes are stocked at levels below 100-150 fry /acre. Stocking frequencies range from annually on lakes that are accessible by roads, or are easily accessible and heavily fished, to once in 10 or more years on remote, seldom-visited wilderness lakes. The statewide mean number of years between stocking is currently about 4 years (Figure 5), although this varies between regions, and is largely dictated by lake access and fishing pressure.

Most WDFW local managers adjust their stocking frequencies (cycles) and fish densities to provide "quality" fish in those lakes where they have the ability to do so (little or no natural reproduction is occurring). Trout or char reproduction in many lakes provides opportunity for "fast" fishing on smaller fish, and thereby offer a consistent fishery for those users who expect to find fish in the lakes. These are often categorized as "family" type waters. While management objectives definitely vary among lakes, with remote wilderness lakes often being managed differently than high lakes that are heavily visited, most WDFW managers try to strike a balance between consistent opportunity (a minimum average catch rate) and overstocking, with the latter's resultant impacts on fish size.

Table 11 illustrates the impact on fish growth that can occur when reproduction is excessive, versus the growth potential of some trout stocks in lakes where fish numbers can be controlled. Two lakes illustrate high and low growth rates that are likely at the extreme ends of the observed spectrum; data from two other lakes are provided for comparison. Fish from stunted growth and fast growth lakes are shown in Plates 36 and 37, respectively.

Table 11. A Comparison of Low (Disciplined Stocking) Density, and High (Reproducing) Density With Trout or Char Length at Age in Six Western Washington High Lakes.

			Mean Total Length at Age (in)			
Lake	**Density**	**Stocked Fry / acre**	**Age 1**	**Age 2**	**Age 3**	**Age 4**
Little Kulla (CT)	Low	64	4.7	7.5		
Thompson (RB)	Low	115	5.4	9.8		
Unnamed[1] (RB)	Low	83	3.9	9.1	12.7	16.2
Elochoman (EB)	Low	125		9.75	11.5	
Hatchet (CT)	High		3.4	5.3	7.3	8.6
Blanca (RB)	High		2.4	3.5	4.8	6.1
Joan (EB)	High					7.4[2]

1 Lake not named due to sensitivity to overfishing.

2 Could not read scales; length at age from otoliths.

Plate 36. Late fall casts a harsh shadow behind stunted eastern brook trout from Joan Lake in the Rapid (Skykomish) River drainage. The fish, 6 to 8 inches long, were 3 to 5 years old. (20 October 1998)

Plate 37. Mount Whitney rainbow exhibit superb condition and fast growth in a lake that is stocked every 4 to 5 years at relatively low density. Skagit River drainage (19 October 1986).

5.4.2.2 *Continuity of Fish Presence*

There has been considerable debate both within WDFW, and between WDFW and sports group members on the relative merits of stocking lakes to maintain a constant presence of fish (albeit at low density), or whether lakes should be allowed to go fallow for a year or two before restocking. Arguments <u>against</u> allowing all fish to die out include:

1) Hiker/anglers who go to the very considerable trouble of arduous back country travel to a lake which has a history of supporting trout should be rewarded by finding at least some in the lake;

2) Stocking a single allotment of Age 0 fry, then allowing that group to age and die from angler harvest or natural causes before restocking creates "boom and bust" fisheries, mostly on fish of Age 2 to 4;

3) Allowing a lake to go fishless may increase the probability of its being illegally stocked, with potentially disastrous results (see Section 5.4.2.4); and

4) Maintenance of a low-density trout population, where one to several year classes of fish are present, does not have an excessive impact on, or eliminate native invertebrates or amphibians.

Arguments <u>for</u> allowing all fish to die out for 1 or 2 years before restocking include:

5) Having fish continually present in a lake, particularly one that can produce "quality" trout, may tend to incrementally increase angler utilization, and may increase shoreline or general environmental overuse impacts. This is a particularly compelling argument for lakes that are currently seldom-visited, or that currently receive only light use;

6) The converse is believed to be equally true – that managing for very low fish density, or fish absence for 1 or 2 years tends to prevent development of a general public expectation that fish and fishing opportunity will always be present at a given lake; and

7) Allowing all or nearly all fish to die out before restocking greatly reduces predation on invertebrates and amphibians for a few years, allowing them to return to pre-stocking levels. The next group of fry stocked then has an optimum food supply to produce the next fishable trout population. This management approach maximizes trout growth rates and flesh table quality.

Although the frequency of stocking, or stocking "cycle" is a fundamental aspect of the management of lakes that require stocking, there is little rigorously-obtained information on these pro and con arguments. As a consequence, opinions vary among both WDFW fishery managers and the sport fishing public on the relative accuracy or relevance of each argument. Variability in lake access, angler use, lake productivity, and other attributes make it even more difficult to determine which of the arguments or paradigms are most often true. In reality and practice, some lakes can or should be managed for periodic fish absence, while in others it makes better sense to maintain at least some fish all of the time. Some additional discussion of the pro and con arguments follows.

Con #1: WDFW managers strive to maximize sport fishing opportunity, while at the same time protecting the subalpine and alpine lake ecosystem, per Fish and Wildlife Commission mandate (see Section 3.0). Having at least some trout in a particular lake at all times should be permissible if it does not eliminate other species, or create intractable management problems for other land and resource managers. Striking this balance requires an understanding of each lake's basic productivity potential and average annual angler harvest or effort level; frequent monitoring; and flexibility by the local, professional fishery manager. As noted by the Commission, the goal of management is to provide opportunity, and opportunity to catch fish still exists even when their numbers are low.

Con #2: There is no question that on average, angler catch rates and catch success are highest the second or third year after fry are stocked in a barren high lake if fish are not stocked annually. The theoretical abundance of fish from year to year following stocking, assuming certain levels of natural and angling mortality, are explored in production model tables presented by Johnston (1973) and Lucas (1989). However, these tables also show that fish are available for up to six or seven years, depending on angling mortality. If angler pressure is high, the remaining fish density can drop fairly rapidly, depending on the initial stocking density, leading to the "boom and bust" phenomenon.

Table 12 shows how the presence of fish over 7 inches can vary, depending on stocking frequency. Given certain assumptions about average natural and angling mortality, the number of years in a decade that fish of this size or larger are present varies from 6 for a 5-year stocking frequency, to 8 for a 4-year cycle (not shown), to continuously for stocking at a 3-year interval or less. The challenge for the local fishery manager is to weigh the relative benefits of providing frequent or continuous fishing opportunity against the potential for ecological impacts at the higher fish densities and stocking frequencies. Even where a 3-year stocking cycle begins with a barren lake, three year classes are continuously present by the 6th year. The model presented in Table 12 is generalized, and certainly does not apply to remote lakes that are seldom visited, or, for lakes that are very productive.

Table 12. Theoretical Comparison 0f Number Of Fish >7" Per Surface Acre Under Differing Stocking Strategies

(5-Year Stocking Cycle and Stocking Rate Of 30 To 100 Fish/Ac in a Lake of Average Productivity). Stocking Years Are Emboldened. Years Where 7" or Larger Fish Exceed 10 Fish/Ac Are Shaded. Adapted From a Table Originally Produced by WDFW Fish Biologist Jim Johnston.

Year:	1	2	3	4	5	6	7	8	9	10
Fish Size at Age	2-3"	7"	9"	11"	12"	13"	14"	15"		
Natural Mortality in Year (%)	5	10	10	25	35	35	45	55		
Total Mortality in Year (%)	5	20	30	50	70	70	70	80		
5-Yr Cycle	1	2	3	4	5	6	7	8	9	10
30/ac	0	23	16	8	2	29	23	16	8	3
50/ac	0	38	27	13	4	49	39	27	14	4
70/ac	0	53	37	19	6	68	55	38	19	6
100/ac	0	76	53	27	8	97	78	65	27	8
3-Yr Cycle	1	2	3	4	5	6	7	8	9	10
30/ac	0	23	16	37	25	17	37	25	17	8
50/ac	0	38	27	61	42	28	61	42	28	14
70/ac	0	53	37	85	59	39	85	59	39	19
100/ac	0	76	53	122	84	56	122	84	56	27

Assumptions: The lake is barren in Year 1. 5% stocking mortality; angling mortality includes catch and release mortality; fish rarely live longer than 7 years.

In summary, WDFW has not prepared a thorough analysis or theoretical model which would effectively prescribe stocking levels and frequencies on individual lakes. Although this would be a valuable management tool, it is questionable whether this is even feasible, given the changes that occur in angler use levels, access conditions, and climate, all of which affect trout survival in lakes, even if a lake's basic productivity potential is fairly constant. The principal value of further development of the mortality analyses prepared by Johnston (1973) and Lucas (1989) may be to further general understanding of the probable range in annual trout mortality. Year to year decisions on stocking density and frequency should be based primarily on the historic stocking record on each lake, subsequent trout growth and condition, evidence of survival of vulnerable trout prey, and the most up-to-date angler reports from the monitoring program.

Con #4: Work conducted by Oregon State University in North Cascades National Park for the National Park Service illustrates that WDFW's low-density trout stocking program does not result in elimination of invertebrate or amphibian taxa (Liss et al. 1995). Abiotic factors may be more important in determining the presence or abundance of salamander larvae (Tyler et al. 1998). Tyler et al. (1998) noted that "the detection of differences in larval densities between fishless lakes and lakes with trout was related to the reproductive status of trout populations, which likely was indicative of trout density and age and the size structure of trout populations". Table 13 provides trout density information on a sample of NCNP lakes that were found to be compatible with native biota. (Larval abundance ranged from zero to nearly 170 per 100 meters of surveyed shoreline in their entire lake sample. More complete information than that presented in Table 10 is currently being prepared by OSU.) Bahls (1990) studied 91 lakes in 1986 and 1987 in the Selway-Bitterroot Wilderness, and found that seven fishless lakes stocked more than 10 years prior to the time of survey showed "no obvious differences from 'pristine' fishless lakes". These studies are taken as good evidence that periodic stocking, particularly when done at low densities, does not lead to invertebrate species extinction. However, Bahls (1990) did not provide data from his study lakes that would indicate whether they supported more than one age class of fish at any point in time. Since invertebrates were not eliminated from lakes where more than one age class was present, fish density appears to be the more important factor leading to severe overgrazing on invertebrates. These results tend to support the argument that periodic stocking leading to the maintenance of multi-aged trout populations in high lakes does not impact native biota unduly, as long as overall fish density is kept low.

Table 13. Empirical Relationship Between Stocking Density and Observed Presence and Abundance of Salamanders and Invertebrates in North Cascades National Park.

Lake	Density of Trout Present (Number / ac)	Salamander Larvae Abundance (No. / 100 m)	Observed Range of Larval Abundance (all lakes)
LS-1	243	20.93	
LS-2	293	0.79	0.0 – 169.7
Upper Panther	243	23.00	
Lower Panther	158	8.71	

Pro #5 & #6: No published information was found that directly supports or refutes the hypothesis that providing fishing opportunity on a consistent basis generates more recreational use on a high lake in Washington than when fish are periodically absent. A practical argument against more frequent stocking (while still keeping fish densities low) is the logistical one of not having sufficient trained personnel available to carry out a significantly larger annual stocking program (a higher number of lakes due to more frequent stocking). This does not directly address the question, however, since in <u>theory</u> a larger stocking workforce could be developed. A rigorous test of the hypothesis would call for selection of a sample of stocked lakes, and altering their treatments, with some being stocked less frequently such that fish die out or become scarce. Recreational angling use of each lake would need to be carefully monitored, probably in conjunction with a user survey to correct for normal year to year variation in use, such as caused by changes in weather or access. The difficulty of monitoring angler use on many wilderness lakes has prevented a suitable test of this hypothesis.

Although Hendee et al. (1977) did not address this hypothesis directly either, their data did show that in moderate to high-use areas, limitations on fishing (i.e., not maintaining a fishable population through stocking) would not have an appreciable effect on user impacts since fishing was either an incidental activity, or anglers were far outnumbered by other users. For virtually all wilderness high lake users, the focal point is the lake (Plates 38, 39, 40). Hendee et al. (1977) note that "modifying the fishery to modify visitation at high lakes is, at best, a partial solution" to overuse problems.

WDFW managers with many years of experience have accumulated considerable anecdotal evidence that in some cases allowing fish to become scarce or absent results in fewer annual visitations, particularly at very remote or difficult to access lakes. Some evidence for large fluctuations in angler use can be found in volunteered angler reports (see Section 5.2.1), but at least some of these are related to the presence of unusually attractive species, such as golden trout. Overall, there has been little or no scientific evaluation in Washington of the numerical response of human visitors to lakes in relation to the abundance or presence of stocked trout. On many wilderness lakes, the number of angling visitors is a small fraction of the total use at or near the lake (Wenatchee and Mt. Baker-Snoqualmie National Forests 1993). Angling is very often an incidental activity for wilderness users, with numerous other aspects of the wilderness experience (e.g., solitude and aesthetics) assuming a much higher value (Hendee et al. 1968). Only 3 percent of users of the Enchantment Lakes area of the Alpine lakes Wilderness listed fishing as their primary activity (Shelby et al. 1989).

(As a side note, a study of "a high influx of backpackers" on two series of lakes in the Sierra Nevada of California concluded that the use did not have a negative effect on alpine lake water quality (Silverman and Erman 1979). The authors also opined that the presence of users at the lakes probably resulted in some reduction in bacterial contamination due to reduced wildlife use of the immediate lake environs.)

Pro #7: There have been no scientific studies in Washington directed specifically at the question of whether allowing fish to die out or become scarce allows complete recovery of a grazed invertebrate or salamander population. Bahls' (1990) survey of over 90 previously-stocked lakes in Idaho strongly suggests allowing a cohort of trout to die out will allow a lake's invertebrate community to recover to its mean annual abundance. What is not known is whether this same recovery would occur even if some small residuum of fish remained in the lake towards the end of a stocking cycle. These points will probably remain largely academic due to the inability of WDFW managers to manage or monitor their lakes at this level of precision.

Empirical observations made by WDFW high lake fishery managers show maintenance of large, conspicuous invertebrates such as *Hesperodiaptomus kenai* in lakes where periodic stocking occurs at moderate levels, such as 50 to 100 fry/acre (Table 7). The managers have also noted that when *H. kenai* is relatively abundant, stocked trout often utilize it as a primary dietary item, resulting in deep orange to red flesh color from astaxanthin and carotenoid pigments (Andre 1926; Miki 1991; Bjerkeng 1997)(Plates 29, 31). Trout which have an abundant macro-zooplankton food supply often exhibit exceptional condition (Galbraith 1975) in Washington high lakes. The high lakes in Washington where this condition exists (high quality trout at low density in sympatry with conspicuous macro-zooplankton) are too numerous to list.

A summary conclusion on the subject of continuity of fish presence cannot be based on hard science from Washington. Studies on the effects of trout presence and abundance on invertebrates (Divens et al. 2001), coupled with the many decades of experience of WDFW high lake fishery managers (Appendix A,

Table1), lead to the general conclusion that in most cases, continual presence of trout, as long as they are not excessively abundant, does not result in overuse of the lake or lakeshore environment, or result in extirpation of invertebrate food supplies. See Section 5.9 for discussion of possible exceptions, particularly with respect to human overuse.

Plate 38. The impact of social trails and heavy recreational use is clearly evident, even from afar, in this view over Silver Lake near Monte Cristo in the Silver Creek and North Fork Skykomish River drainage. Silver Lake has never supported fish due to high mineral content, which illustrates the fact that the aesthetics of the lake and surrounding environment is often the overriding factor driving use levels. Eight people are crowded into a thin space 20 feet wide along the lakeshore on (1 August 1996) (bottom of photo).

Plate 39. Heavy camping and wandering have left large areas of bare mineral soil at Silver Lake (1 August 1996).

Plate 40. Heavy recreational use at fishless Silver Lake has prompted the Skykomish Ranger District to attempt vegetation recovery. (1 August 1996)

5.4.2.3 *Termination of Stocking in Individual Lakes*

Lakes with a history of trout stocking are occasionally removed from the stocking program. Reasons to terminate stocking include:

- Initiation of, or an increase in natural reproduction by trout or char in the lake (see Section 5.6.1);
- New knowledge that natural reproduction is occurring in the lake, and is sufficient to support the fishery;
- Complete loss of angler access;
- As part of a coordinated regional approach to managing the high lake fishery, in cooperation with other land managers (USFS, NPS), where new fisheries are created to replace those eliminated.

The decline in the number of lakes being stocked (Figure 3) is almost wholly due to changes in fish reproductive status – either trout or char have begun to spawn in lakes where they did not in the past, or recent surveys have documented spawning that had previously not been discerned or reported. Most of the few remaining lakes that have been dropped from the stocking program are on lands administered by the USFS or NPS. However, it is important to note that no new lakes on federal lands were added to the program to offset those that were lost due to the creation of the North Cascades National Park (see Section 5.9.2).

5.4.2.4 *Termination of a Managed Stocking Program*

Large numbers of the sport fishing public desire lake fishing opportunity in Washington’s back country and wilderness areas (WDFW 1996a). The experience of long-tenured district fishery biologists (Appendix A, Table 1) has clearly shown that some members of the angling public are perfectly willing and able to pack fish into their favorite lake, despite this being illegal (RCW 77.15.250; RCW 77.15.290). In rare instances anglers have contacted a local WDFW biologist before taking this drastic step (e.g., a documented case involving Joe and Edds Lakes on either side of the Pacific Crest Trail [WDFW Mill Creek regional office files]). Recently, lakes in Mount Rainier National Park and in the Mount St. Helens National Volcanic Monument in which fish have been removed or died out have been illegally re-stocked by members of the public. Bootleg stocking of miscellaneous small lakes has been a problem for many years, but has been reduced to a very low level in the past 10 to 15 years.

Much of the perceived reduction in illegal stocking is probably due to the more disciplined (higher quality) nature of the WDFW high lake fishery management program that has developed in the last 25 years. Elimination of a controlled, professionally-managed stocking program in wilderness or backcountry areas runs the very real risk of spurring an increase in illegal stocking. In many cases, probably a majority, readily-available species from lakes already overrun with reproducing fish would be chosen as sources of fry. Thus, eastern brook trout or westslope cutthroat would probably be the most common species illegally transferred to lakes that were dropped from their historic stocking regimes. This would have the definite effect of creating additional spawning populations and excessive fish abundance in some of, perhaps most of the lakes, rather than maintaining quality fisheries based on low-density, periodic stocking of species and strains which cannot or do not reproduce. In most cases illegal introduction of these “volatile” species would simply increase the number of lakes impacted by excessive numbers of trout or char, rather than maintaining a fish density which has been shown to be compatible with native invertebrates and amphibians in Washington (Divens et al. 2001).

It is also very important to note that creation of new, self-sustaining fish populations would be essentially irreversible in some lakes due to the physical impossibility of totally removing all fish, chemically or otherwise. WDFW has been experimenting with biological controls in lakes such as these, with very limited positive results (see Section 5.7.2).

5.4.3 Species and Stock Selection

See Crawford (1979) for a partial description of the individual species stocks and strains used in the historic and current WDFW high lake program. Crawford did not review all strains that have been used in Washington in the latter 20th century, but limited his review to those brood stocks maintained by the State of Washington. Numerous other strains and species have been used or tested since 1970. WDFW local managers choose species to stock based on the following considerations:

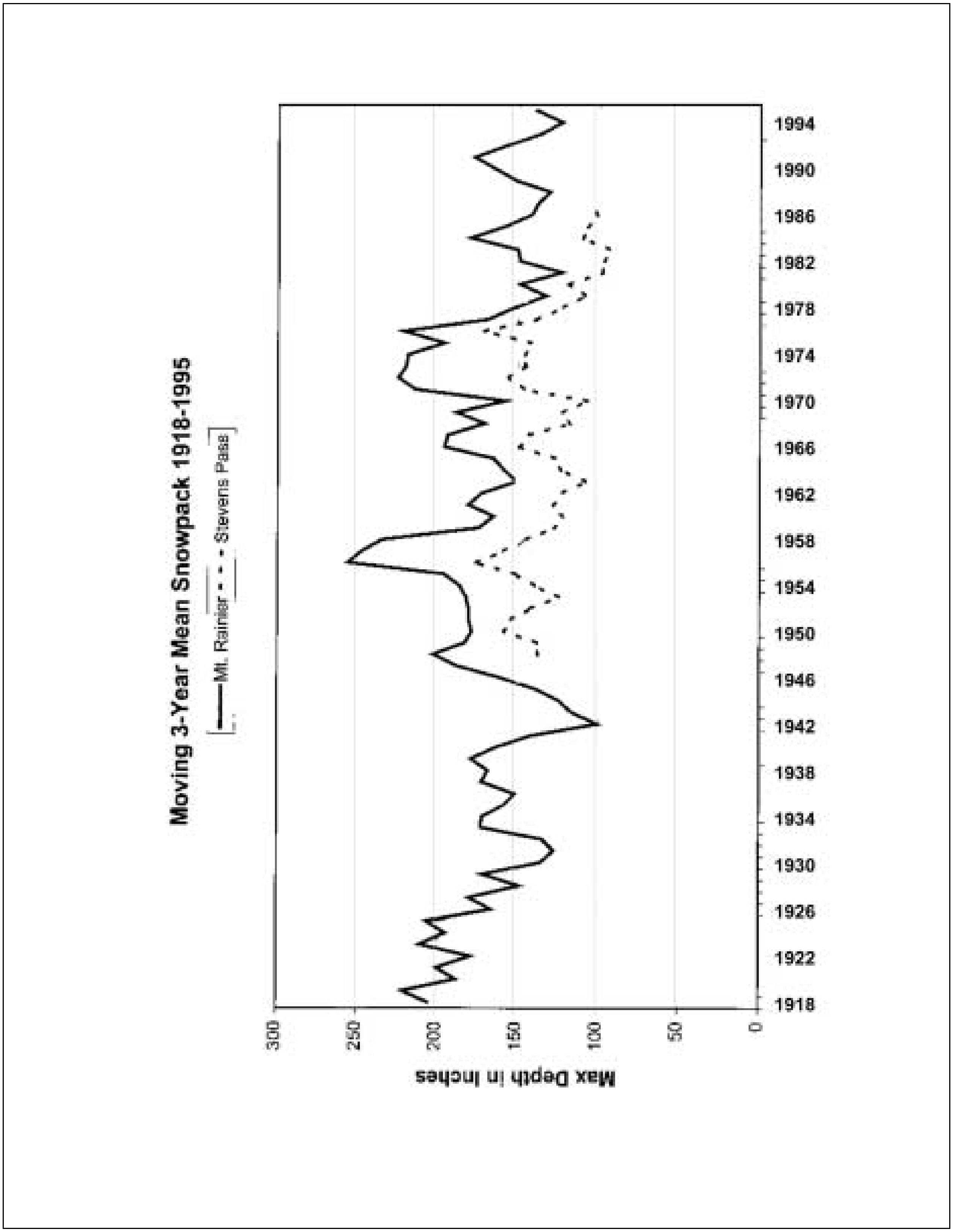
- The current species present in the lake, and its past performance;
- Whether greater program diversity is needed or desirable on a local regional basis (WDG 1981);
- As part of on-going evaluations of potential apex predators (biological controls) in lakes with stunted trout or char populations (see Section 5.7.2);
- Whether emigration or fallout and downstream genetic impacts are a current or potential problem; and
- To assess the performance (sporting qualities, growth characteristics, etc.) of a new strain.

In general, if the species is or are performing well in a lake that requires periodic stocking, the species or strain/s will continue to be stocked. Monitoring of the fishery in individual lakes is, therefore, a critical management element, and serves to alert the manager of changes in species or stock performance. A perfect example is the development of successfully reproducing populations of Twin Lakes (westslope) cutthroat in lakes where they did not reproduce in the past. Use of this stock has nearly ceased in most areas of western Washington as a result, but the strain is still used extensively in eastern Washington.

(The cause/s of the remarkable increase in spawning success of Twin Lakes cutthroat in western Washington lakes where they did not formerly reproduce remain a mystery, and the subject of considerable conjecture. Mechanisms suggested include inadvertent selection of more beach or alluvial fan spawners from the Twin Lakes, or longer open water periods due to climate change. The latter theory seems more likely since spawner collection methods have changed very little at the Twin Lakes in recent decades. Earlier clearing of lakes and longer open-water periods in stocked lakes could allow more temperature units to be accumulated by incubating eggs laid in tributaries, resulting in either successful fry emergence before winter, or earlier fry entry into the lake and longer feeding before winter conditions set in. Either of these scenarios could result in the observed increased survival of naturally-spawned westslope cutthroat fry. Support for the longer open-water theory is found in Figure 12, which suggest a declining trend in peak snow pack from the early 1970s, particularly in the north central Cascades as indexed by depths taken at Stevens Pass.

Providing a diversity of species and strains within management districts has varied among the WDFW local managers. Some have used one or two species almost exclusively (e.g., Twin Lakes cutthroat in Okanogan County lakes). The greatest level of experimentation and use of diverse strains has been in King, Snohomish, Skagit, and Whatcom County lakes, where up to 16 strains of trout and char have been available within a 75 mile radius of Seattle (Curtis and Erickson 1992; Mottram 1994). See Section 5.5.4

Figure 12. Moving 3-Year Mean Maximum Snow Pack Depth at Mt. Rainier And Stevens Pass, 1918-1995.



for a list of the species and strains that have been used. Notable past species tests included atlantic salmon (*Salmo salar*), which have exhibited superior sporting qualities and growth where tested, except when in competition with rainbow (Plates 41 and 42). Brown trout have attained large size and excellent condition in a number of lakes where they have been introduced to serve as top predators on stunted fish (see Section 5.7.2).

Although some of the most regrettable early introductions involved eastern brook trout, this species provides excellent diversity, sporting characteristics, and table quality where its numbers can be controlled (Plate 43). Use of eastern brook trout is most common in the southern Cascades (Cowlitz, Lewis and Skamania Counties) where it has performed well in many lakes for many years, and where hybridization issues with native char are not a concern (e.g., in lakes with no surface outlet).

Arctic grayling (*Thymallus arcticus*) were stocked in three or four disparate locations in western Washington in the mid-1940s, but only survived in one high lake in the Skagit River drainage. They continue to be a very popular draw for serious anglers interested in experiencing this species in Washington. Although a number of local managers are still interested in utilizing this species in a very limited number of other lakes, there is no readily available source of fry.

Lake trout (*Salvelinus namaycush*; Plate 44) were stocked very early in the 20th century in a small number of lakes (Piper & Taft, Inc. 1925). Self-sustaining populations occur in only two or three high lakes statewide. New introductions are rare, and have been limited to lakes where they have been introduced in the past, or as a test of their ability to control stunted eastern brook trout (Section 5.7.2).

A variety of rainbow and cutthroat strains have been tested by the Trail Blazers, Inc. with WDFW permission (see Section 5.5.4). Anecdotal information, some of which is documented in volunteered angler reports (Section 5.2.1), indicates sport quality and growth was exceptional for most of the varieties, particularly when they did not have to compete with reproducing fish. However, some strains seemed to compete better with stunted species than the traditional strains used by WDFW. Hybrid crosses, notably steelhead x golden trout, have been reported to exhibit many of these same characteristics (hard fighting, fast growth, exceptional appearance, etc.). Limited evaluation of the use of these hybrids to control stunted fish is currently underway (WDFW 1995b).

5.4.4 Genetic Impacts & Ecological Interaction

Since virtually all high lakes in Washington were originally fishless, genetic impacts from trout or char stocked into high lakes, if any, would generally be limited to native fish that exist downstream from the stocked lake. (See Section 5.6.2.) WDFW local managers are aware of the need to consider the potential for dropout or emigration from stocked lakes, and possible interbreeding with native salmonids. Native stocks used on the eastside of the Cascades include Twin Lakes (west slope) cutthroat (Plate 45). In western Washington Tokul Creek (coastal) cutthroat (see Section 5.5.2) have been used, and their use is being expanded as a substitute for Twin Lakes cutthroat. Rainbow in the Skagit River above Gorge, Diablo, and Ross Dams are being considered for development as a native stock that can be used as a substitute for Mount Whitney rainbow, where appropriate.

Native bull trout or Dolly Varden are currently being considered as apex predators in lakes where biological control of excessively abundant char or trout is desired. No brood collections or fry introductions have been made, but char stocks native to the river basin would be used in test lakes located in the same watershed from which the brood fish were obtained.

Plate 41. Two atlantic salmon (outer fish) and one Mount Whitney rainbow from Nine Hour Lake in the Middle Fork Snoqualmie River drainage, (4 September 1985). The salmon are 4 years old.

Plate 42. Four Atlantic salmon from Lake Serene, Skykomish River drainage (11 July 1978). Although the fish fought well, they exhibited slow growth when in competition with rainbow in this lake. The salmon were 3 years old

Plate 43. Eastern brook trout commonly grow well and exhibit fine condition in lakes in the southern Cascades and Indian Heaven wilderness. Stunted populations are far less common in this geographic region. John Thomas photo.

Plate 44. Lake trout from Eightmile Lake, Icicle Creek and Wenatchee River drainage. G. Ring Erickson photo.

Plate 45. Twin Lakes (west slope) cutthroat exhibit classic spotting and fine coloration in Little Cougar Lake, North Fork Snoqualmie River drainage. (25 September 1991)

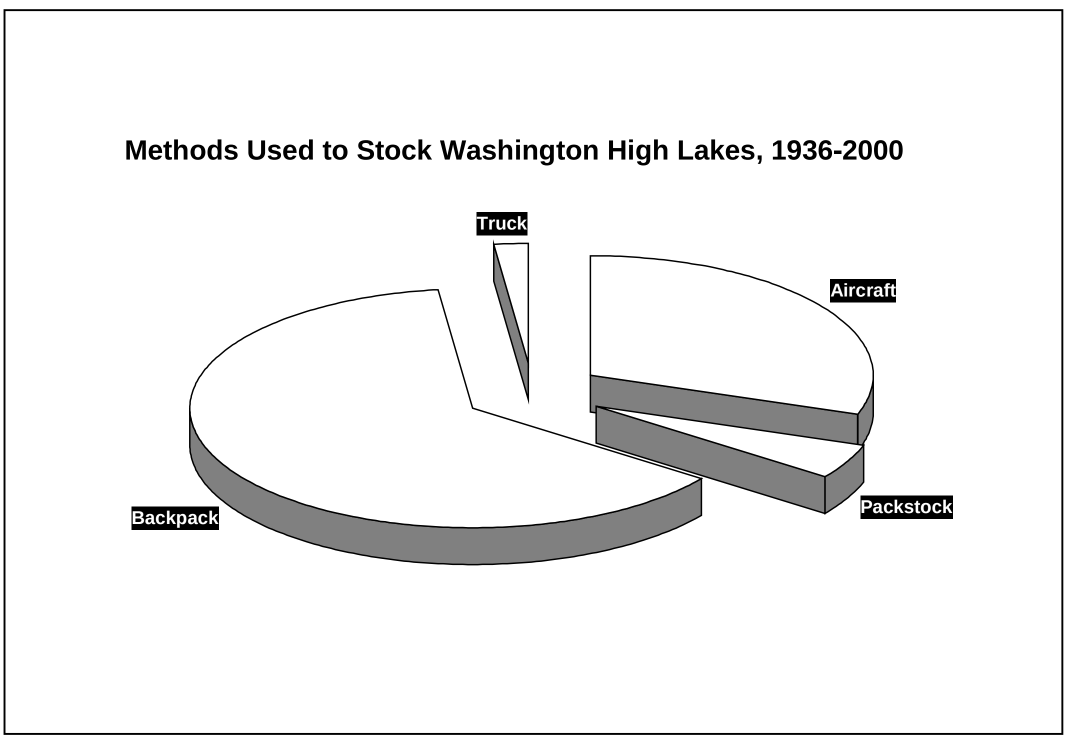
Ecological interaction considerations are primarily limited to stocking densities (see Section 5.4.2). WDFW local managers were essentially unanimous in noting that where problems are known to exist with dropout of non-native species, they are in systems where non-native fish were stocked in the distant past (Parametrix 2001; Table 19). Although wildlife benefits are rarely, if ever a consideration in species selection or other decisions regarding stocking, some wildlife considerations (ecological interactions) affect the stocking program or the fishing season (see Sections 5.6.3 and 5.9.2).

5.4.5 Stocking Methods and Quality Control

Like most of the western states, the WDFW stocks its high lakes by a variety of methods (Figure 13; n=5756 introductions). Lakes are stocked both from the ground and from the air, using one of the following methods:

- Standard hatchery tank truck and hose;
- Pickup truck or flatbed, generally with a small tank, from which fry are packed a short distance;
- Backpacking of small containers;
- Horse packing of medium-sized containers (panniers);
- Air drops from fixed-wing aircraft; and
- Air drops or shore-based hand release of fish from helicopters.

Figure 13. Distribution of methods used to stock trout fry into Washington high lakes, 1936-2000.



Two actions are accomplished in all methods where fish are released by hand directly into the lake. These are tempering (gradual equilibration of the transport water temperature to that of the receiving water), and careful observation of fry behavior. Tempering can be, and is accomplished as necessary in all but direct dumps from a large truck tank, from fixed wing aircraft, and from helicopters if they cannot land. Tempering is advisable if water temperatures differ by 10 degrees Fahrenheit or more, particularly if the lake is warmer than the transport water. If fish exhibit erratic behavior or loss of equilibrium even after water tempering, they are observed for up to one half hour to judge the extent of hauling loss. Careful observation of fry behavior and condition is common to all release methods where fish are released by hand. Therefore, short pack from a truck, backpack, horse pack, and landed helicopter are the preferred methods since they allow a much more accurate gauging of the actual number of fry that survive the stocking operation.

5.4.5.1 *Truck Methods*

Road access allows standard truck stocking at a very small percentage of high lakes. Although in some cases it is possible to literally back a truck up to the lake and dispense fry with a hose, it is usually more convenient to contain the fry allotment in a screened fry bucket suspended within the larger truck tank (Plate 46). The fry are hand-stocked from this bucket into the lake, and note taken of any hauling or handling stress or loss.

A more common situation is logging road access to near, but not all the way to a lake. At this point fry are transferred from a fry bucket to a container that can be conveniently carried or backpacked to the lake.

Note is taken of any fish loss upon release, as noted above. The only significant differences between this "truck method" and "backpacking", below, are the distance the fish must be hauled to the lake/s, the condition of the access road, and the number of fry that must be stocked. Agency hatchery trucks with their larger 200 to 500 gallon tanks are only used where road conditions allow, and it is practical to hand pack or backpack the fish to the lake/s. For large numbers or poundage of fish, it is usually more cost-effective to use aircraft.

Data quality control is generally very good with truck stocking since trained and experienced hatchery personnel observe the condition and behavior of released fish. Hatchery stocking reports are adjusted to account for any observed losses.

Plate 46. Individual lake fry allotments are kept separate in screened buckets sealed with small-mesh netting material. (The tank aerators are turned off.) Arlington airport tarmac, (20 August 1986).

5.4.5.2 *Backpack and Horse Pack Methods*

At the hatchery, relatively small numbers of fry are loaded into lightweight containers (Plate 47) that are cooled in an ice chest (or facsimile) en route to the trailhead. The containers are wrapped in suitable insulation for transport in a pannier, or in a backpack. Water sloshing en route serves to maintain aeration and dissolved oxygen levels in the container water, but volunteers and agency personnel are trained and experienced to be aware of the time limitations under which fish can be transported in a sealed container (Gebhards 1965). If necessary, water is exchanged en route to the lake/s. At the lake, the container is opened to the atmosphere, and dissolved gases are allowed to equilibrate, particularly blood gases in the fish. If necessary, the container is placed into the lake as part of the tempering process. Fish are released slowly into shoreline areas (Plate 48) where refuge from predators (birds, mammals, large fish, even adult salamanders) is available (talus interstices, complex woody debris, etc.). Notes are taken on the container and lake water temperatures, and any relevant observations on fish behavior, particularly mortalities.

Stocking data quality control is generally good, often excellent with backpack or horse pack methods since experienced volunteers or agency staff generally have the time and opportunity to carefully observe the fish they release. Special forms and procedures have been established wherein the Trail Blazers adjust the allotment number noted at the hatchery at trip departure by the number of fry lost en route or at the lake, if any. This quality control check is not possible with fixed wing stocking, or helicopter stocking if the helicopter cannot land to allow hand release of the fish.

5.4.5.3 *Fixed Wing Aircraft*

The earliest air stocking of salmonid fry may have been by Prevost (1935) in the early 1930s in the Quebec region of Canada (Gaub and Hodges 1996). Similar methods were soon emulated in Montana in "the 1930s", where methods were tested and developed which are still in use today: direct dumping of fry and their transport water from heights of 100 to 1000 feet (Gaub and Hodges 1996). Other states, such as New York (Lindsey 1959), similarly began air stocking in the 1930s, and developed their own aircraft-based stocking program. Initial air releases in Washington occurred at about this same time; Otter Lake in the current Alpine Lakes Wilderness Area was stocked in 1938 with containers to which small parachutes were attached (Yadon et al. 1993). California also experimented with cans hung from parachutes, making such drops in 1946 (Leitritz 1951).

Extensive experimentation in California and Washington in the first years after World War II (1946 and 1947) determined the optimum size of fish that could be dropped without significant mortality, and from what heights (Leitritz 1951). Although the 1946-47 California experiments found that the "most suitable height" was 300 to 800 feet, and that trout up to 4 inches could be dropped without mortality, instantaneous mortality became significant beyond that size, and was 100 percent for 15 inch trout (Leitritz 1951).

Fry dropped from fixed-wing aircraft appear to fare well and behave normally upon hitting the lake (Leitritz 1951; Pfeifer 1986a), and fry can be dropped quite accurately from fixed-wing aircraft into lakes as small as 2 to 3 acres (Leitritz 1951). These short-term results tend to give confidence that small to large mountain lakes can be successfully stocked from the air, and that the number of surviving fish is known. However, sampling of Ontario lakes with gill nets 2 to 4 months after air stocking suggested delayed mortality can occur (Fraser 1968). Fraser (1968) found that backpacking and hand stocking of fish that had received similar culture resulted in higher survival than that seen in air-dropped fish.

Plate 47. Plastic containers that hold up to 2.5 gallons are ideal for packing small quantities of trout fry. A good deal of experience and technical know-how is required to transport this many fry to a remote lake without mortality. (9 September 1979)

Plate 48. Fry are released into an areas where they have some cover from predators. Tempering of the transport water, and collection of lake water temperature are routine tasks. Careful observation of fry behavior after release yields high reliability in the stocking record. Round Lake, Whitechuck River drainage (9 September 1979).

Typical equipment used to carry fish in fixed-wing aircraft has been described by Leitritz (1951) and Loftus (1956). The water used to carry the fry is kept cool and aerated en route to the lakes, but atomizes into a cloud immediately upon release (Plate 49). The fry "float like feathers to the water" (Gaub and Hodges 1996), as they achieve a terminal velocity of about 50 feet per second, or approximately 28 mph (Leitritz 1951). The fish have a trajectory of about 200 feet from an aircraft traveling at 120 mph, and then fall straight down unless drifted by the wind. "The accuracy with which the target area can be hit is most surprising" (Leitritz 1951). Although Leitritz (1951) was enthusiastic about drop accuracy, WDFW experience has shown that the fry dimple pattern clearly seen on the lake after the drop (Garlick 1950) can sometimes extend into shoreline areas of very small lakes unless wind conditions and pilot judgment are ideal. Therefore, lakes smaller than 5 acres generally are not stocked with fixed-wing aircraft. (Note that should some fry be dropped into shoreline areas, the lake is effectively understocked, not overstocked, and the principal adverse effect is poor record-keeping, and perhaps a lessened ability to correlate stocking density with other variables of interest, such as fish growth.)

A modern, multi-chambered drop tank (described and depicted at http://www.soloy.com) has been custom-designed for one of WDFW's de Havilland Beavers (Plates 50, 51). Its function is similar to equipment described by Garlick (1950), Leitritz (1951), and Loftus (1956), but is enhanced by the ability to load up to nine tanks with fry aliquots for up to nine lakes while still on the tarmac. There is no need to transfer fry from one container to another once underway. A pilot checklist correlates tank numbers with the target lakes, and each tank's drop solenoid switch (Plate 52).

The WDFW Beavers are equipped with Global Positioning System (GPS) instrumentation that allows the latitude and longitude coordinates of target lakes to be keyed into onboard avionics. Flight time is minimized as the pilot can follow a displayed bearing directly to the lake/s. If the target lake is the only one in the general area, there is virtually no chance that the wrong lake would be stocked. However, lakes are frequently closely clustered in the Cascades. Stocking of the correct lakes is virtually assured if an observer who is familiar with the target lakes and terrain accompanies the pilot. This has been a common practice in the WDFW fixed-wing stocking program for many years.

Stocking data quality control consists of the pilot coordinating closely with the hatchery staff when the fry are loaded (Plate 53), and reporting any fry losses due to equipment failure (rare). In virtually all cases, the number of fry loaded by the hatchery staff at the airfield is the number that is effectively stocked into the correct lake. The potential for stocking the wrong lake has been eliminated, but occasional problems with aeration equipment can lead to fish being dropped that are not in ideal condition. Some delayed mortality can occur under these circumstances (Fraser 1968), but the number of fish lost is never known.

This is the most significant drawback to fixed wing stocking, but this error source is minimized by flying when weather conditions are good or ideal, stocking only healthy fish, not stocking small lakes, and using skilled, experienced personnel.

Fish survival and the accuracy of stocking data is further optimized by stocking the lakes as early in the season as possible. This tends to minimize the difference between lake surface water temperature and that of the water in the drop tank containers. For certain species that must be stocked late in the summer due to spawning timing, potential temperature shock can be minimized by transporting fry to the airfield in a tank that has been allowed to sit out overnight for 12 to 18 hours. Some states have had success in stocking small fingerlings up to 4 inches long in the fall, when ponds and lakes have cooled to temperatures closer to that of the hatchery water supply (Lindsey 1959). While survival of fall-stocked 4 inch eastern brook trout was excellent in New York, fish stocks used in Washington are far smaller in the fall, and their survival is sharply reduced if fry cannot acclimate to the lake and its food supply before winter. Thus, fall stocking to avoid temperature shock is generally not an option in Washington.

Plate 49. The 4 to 5 gallons of transport water quickly atomizes upon release, but the fry fall nearly straight down several hundred feet to the target lake. Kelcema Lake, Stillaguamish River drainage, (21 August 1986).

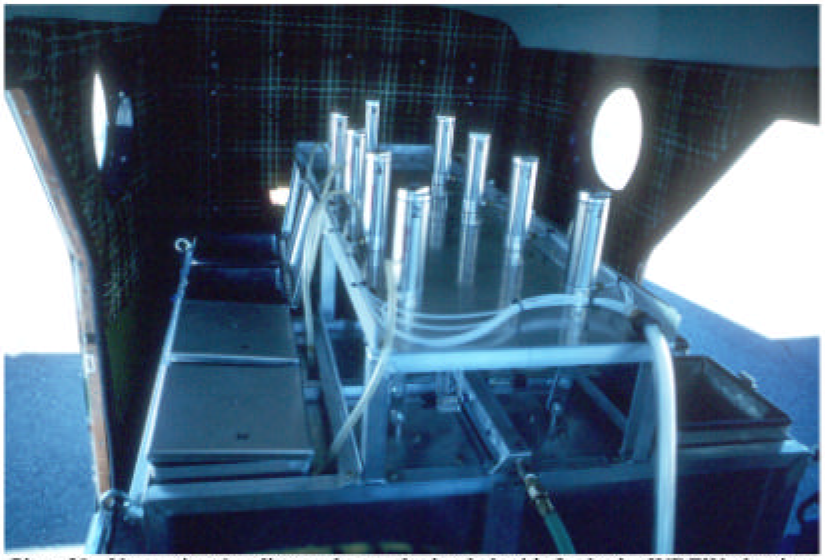


Plate 50. Up to nine 6-gallon tanks can be loaded with fry in the WDFW planting tank built by Soloy Corporation. Compressed oxygen can be metered at individual rates to each tank, and flow is automatically shut off when the fish are released. Nine release valve solenoids are visible, and are controlled remotely by the pilot. Each tank and solenoid is numbered, which coincides with numbering on the release toggle panel.

Plate 51. The drop tank was designed for the deHavilland Beaver. The drop tube is seen exiting the camera port to the left of the step, and below the fuselage port-hole. The individual tanks are loaded from both sides of the plane. Darrington airfield, (30 September 1998)

Plate 52. Release of tanks 1 through 8 places fry and water in the 9th tank, which is controlled by the far left toggle switch. The 9th, or posterior "ready" tank is dumped when in position over the target lake. Photo by Soloy Corporation.

Plate 53. The hatchery Manager (with clipboard) carefully discusses the fry stocking allotment with the pilot for all lakes to be stocked on an individual flight. Arlington airport, (20 August 1986).

5.4.5.4 *Helicopter Stocking*

Helicopters have been used to stock high lakes in Washington since the Korean War. They were used in cooperative stocking programs between the U.S. Fish and Wildlife Service and the National Park Service to stock high lakes in Olympic National Park (Garlick 1950). More recently, WDFW local managers have used helicopters leased from private operators (Plate 54), and in cooperative, no-cost arrangements with private helicopter owners, major timber owners, the Washington Air National Guard (Plates 55, 56), and the U.S. Forest Service.

Helicopters are more costly to operate on an hourly basis than the agency's Beaver, but have several distinct advantages:

- Leased, or volunteered/cooperative helicopters are generally available on short notice, whereas the agency Beaver may be down for service, or being used for other agency business;

- Helicopters can access virtually any lake, but geographic setting and lake size are distinct limitations on whether they can be stocked using fixed wing;

- The ability to hover over a lake or land nearby allows much greater flexibility in assuring all fry are placed into the lake, and allows slow hand tempering under unusual circumstances. Both hovering close to the lake and shore-based tempering increase the probability of fry survival, and more accurate stocking records.

- Apart from a brief noise intrusion, helicopter stocking avoids all other impacts on the surrounding environment that may be associated with a stocking crew or pack stock.

Since helicopter stocking essentially replaces human backpacking or horse packing labor to reach the lake, it is used either for waters that require a large number of fry, or in areas where agency staff, volunteer labor, or the agency Beaver are not available. It is possible to land at most non-wilderness lakes, which allows hand-stocking and tempering of fry from small containers that have been prepared before the flight in the same manner as for backpacking. Otherwise, the container of fry is simply poured into the lake from the hovering ship. The local WDFW management biologist usually accompanies the pilot on all helicopter stocking, assuring that the correct lakes are stocked.

Plate 54. Under some special circumstances it is desirable to have high confidence in the number of fish surviving an introduction, such as under research conditions. It is often feasible to land a small helicopter near a lake to be stocked. The fish can then be hand released with care, in the same manner as those brought in by backpack. Small helicopters can also ferry supplies for chemical treatments (see Section 5.7.1) with little or no impact on the general lake environment.

Plate 55. National Guard personnel gain valuable air time in mountainous terrain when assisting WDFW with fish stocking. Bags of fry are in the black 5-gallon buckets. The Regional Fish Biologist discusses the fry allotment with a crew member. Private airstrip near the Tokul Creek Hatchery at Snoqualmie, (Fall 1976).

Plate 56. The bags of fry can be dumped directly from the hovering ship, or be carried to the lake if the ship lands. (Heather Lake, 29 August 1978.)

Lake Management Approaches

The department generally manages each high lake with one of four basic approaches, or objectives (WDFW 1996b). These are:

1) Maximum sustainable yield fishery – recreation emphasis (“Flexible Management Waters”);

2) Optimum sustainable yield fishery – recreation emphasis (may include “Sustainable Wild Production Waters”);

3) Larger waters purposefully managed as fishless – “Special Protection” (ecological / scientific reserve emphasis); and

4) Small, fishless waters – “Special Protection” (ecological / scientific reserve emphasis).

The first category includes, by default, all lakes that have naturally-reproducing trout or char populations where fish are excessively abundant. Other lakes managed with approach 1 could include those having all of the following characteristics: periodically stocked, high angler use levels, and easy access. “Flexible Management Waters” are lakes (or streams) with no native species preservation concerns.

Lakes managed with approach 2 are the many lakes where the local manager regulates fish stocking frequency and density to produce fish of high quality, usually not quantity (see Section 5.4.2). Fishing may range from fast to slow, depending on factors such as weather, insect hatches, etc. Most waters in this class are on a periodic stocking cycle, so fish abundance is low in some years, leading to slow fishing (see Section 5.4.2). This is offset by the important objectives of preservation of all invertebrate taxa in the lake, and production of consistently high quality trout. “Sustainable Wild Production Waters” is a classification that has better application to streams with native fish species than high lakes with fish introduced for the purpose of providing recreation. There are a very few high lakes in this classification that have naturally-reproducing native fish that provide a recreational fishery.

Approach 3 lakes occur most frequently in designated wilderness, or in one of the state’s national parks. “Special Protection Waters” includes lakes or streams that are managed for native species only, with no supplemental trout stocking. These waters may or may not have historically contained fish.

With the exception of a subset of lakes in North Cascades National Park, no trout stocking occurs in lakes and ponds in the state’s national parks (Olympic, Mt. Rainier, North Cascades), or in a number of waters in Natural Resource Conservation Areas managed by the Washington Department of Natural Resources (Class 3 and 4 waters). This results in literally thousands of lakes and small tarns that can be managed and studied for their natural condition and ecological communities Tables 12, 14). This management approach also provides many lakes and ponds across the landscape that can serve as habitat or refugia for various species of invertebrates or amphibians (Appendix Plate K-2). Although the percentages vary from region to region, an average of 62 percent of ponds and lakes larger than 0.1 acre are managed for a fishless condition (below). These include lakes that are over 10 to 20 feet deep, which are preferred by some invertebrate and amphibian species. Table 14 gives the physical characteristics of some lakes in WDFW Region Four that are capable of being managed for a fishery, but which are purposefully left fishless. These lakes represent a range in elevation, size, and depth, and are only a very small subsample of the many fishless waters.

Table 14. Physical Characteristics of 10 Lakes Managed for a Fishless Condition in or Near the Western Half of The Alpine Lakes Wilderness, Washington

Lake	Elevation (ft msl)	Surface Area (ac)	Max Depth (ft)	Mean Depth (ft)
Gem	4857	14.9	148	50
Chair Peak	4950	5.0	105	80
Findley	3710	22.3	55	26
Lower Sutton	3610	1.3	9	6.5
Bear	4180	2.8	16	6
Quartz	4800	1.0	9.5	7
Lower Tank	5800	4.0	16	10
S.M.C.	3702	40.7	180	81
Nadeau	3722	18.9	77	32
Moolock	3903	45.4	150	57

Information on the number of lakes and ponds present in a geographic area, and the number of these supporting fish, is available in most areas of Washington. The number and percentage of all Washington high lakes that are left in their natural condition can be approximated by an indirect approach. The most recent mapping of "high" lakes and ponds in Washington's Cascades and Olympics yields a total of 4718 waters 0.1 acre or larger (Trail Blazers, Inc. HLS database). A total of 1777 waters are currently under some sort of stocking regime, or are known to have self-sustaining fish populations. Discounting the very small percentage of unsurveyed waters that may have wild fish populations, about 62 percent of Washington high lakes and ponds 0.1 acre or larger are known or presumed to be fishless. Table 15 presents data from districts where all waters over 0.1 acre have been catalogued for fish presence. One may safely assume that few to none of the unsurveyed ponds less than 0.1 acre contain self-sustaining fish.

Table 15. The Total Number of Lakes and Ponds 0.1 Acre and Larger With and Without Fish (as of 2001) Mapped (USGS) at the 1:24,000 Scale, by WDFW Administrative Region[1]

Administrative Region	Number of High Lakes and Ponds	Number of High Lakes and Ponds With Fish[2] (%)	Number of High Lakes and Ponds Lacking Fish (%)
1	31	3 (10)	28 (90)
2	723	331 (46)	392 (54)
3	588	227 (39)	361 (61)
4	1638	838 (51)	810 (49)
5	710	206 (29)	504 (71)
6	1028	182 (18)	846 (82)
All Regions	4718	1777 (38)	2941 (62)

[1] Includes waters in all national parks, plus the Yakama Nation.
[2] Waters with stocking record, or in which fish have been seen.

Designated wilderness areas in Washington typically have examples of all four of these management approaches. Table 16 gives representative statistics for two wilderness areas in the southern half of WDFW Region Four (Region Four includes all or portions of six wilderness areas, plus two national parks).

Table 16. The Number and Percent of Wilderness High Lakes and Ponds in Southern WDFW Region Four in Each of Four Management Approaches as of 2001.

Wilderness	Management Approach	Number of Lakes/Ponds (%)
Alpine Lakes (west side)	1	49 (13)
(385)	2	81 (21)
	3	8 (2)
	4	247 (64)
Henry M. Jackson (west side)	1	6 (17)
(35)	2	6 (17)
	3	2 (6)
	4	21 (60)

Table 17 was prepared to give perspective on the number of managed high lakes in Washington wilderness areas.

Table 17. The Number of Stocked[1] Fish-Bearing Lakes, and Non-Stocked Fishless Lakes and Ponds In Wilderness Areas of Washington By WDFW Administrative Region as of 2001.

Region	Total Waters	Number of Lakes and Ponds in Wilderness[2] (%)	Stocked or Fish-Bearing Wilderness Waters (%)		Non-Stocked, Fishless Wilderness Waters (%)
			All Plants	Since 1970	
1	31	10 (32)	3 (30)	3 (30)	7 (70)
2	723	536 (74)	223 (42)	186 (35)	313 (58)
3	588	383 (65)	137 (36)	120 (31)	246 (64)
4	1638	737 (45)	396 (54)	355 (48)	341 (46)
5	710	392 (55)	72 (18)	66 (17)	320 (82)
6	1028	104 (10)	37 (36)	27 (26)	67 (64)
All	4718	2162 (46)	868 (40)	757 (35)	1294 (60)

[1] Many lakes that were stocked in the past developed reproducing fish populations, and are no longer stocked.
[2] Excludes waters in national parks and the Yakama Indian Nation.

Management of many lakes and ponds for a fishless condition is not unique to Washington. Gaub and Hodges (1996) noted that in Montana "Lakes are usually stocked every 3 to 6 years. Not all high mountain lakes are stocked; many are intentionally left fishless to preserve their unique biological characteristics".

5.4.6 Assessment and Recommendations

Local WDFW management biologists unanimously agree that knowledge of the reproduction status of trout populations in their high lakes is a foremost concern in setting stocking rates and frequencies. However, a few districts still have significant numbers of lakes where this information has not been obtained due to the number of lakes present, and lack of human resources.

Recommendation #1: Resources should be focused on obtaining critical information on fish reproductive status from the remaining lakes where it is lacking (primarily Skamania, Klickitat, Yakima, and Chelan Counties). Reproduction must be determined by on-lake surveys. The information should be obtained from WDFW staff, experienced consultants, trained graduate students, or trained volunteers, in that order of priority. Anecdotal information should never be relied on when making a reproduction status determination.

There is a general lack of well-researched information on natural and angling mortality of trout and char in Washington high lakes. Managers have used mortality estimates based on personal experience, with some guidance from published information from other states or provinces. Stocking frequency decisions would benefit from a better understanding of the range of natural and angling mortality seen, particularly if assessed from lakes stratified on the basis of geographic location, and annual level of angler effort. The information would also need to be stratified by fish species.

Recommendation #2: Specific research should be directed at obtaining estimates of natural and angling mortality for trout and char in Washington high lakes. This would be an excellent cooperative project with the Forest Service and/or North Cascades National Park.

Arguments can be made both pro and con for maintaining a continuous presence of fish in high lakes through periodic stocking (as opposed to the presence of reproducing populations, which tend to be too dense). Recent studies have shown that invertebrate and amphibian taxa can co-exist with trout as long as trout densities are kept low (Divens et al. 2001). These studies have generally not evaluated whether *continual* fish presence, even if low, has unacceptable impacts on other biota. There have also been no studies to test the hypothesis that allowing fish abundance to drop to very low levels for 1 or 2 years results in reduced recreational pressure at a lake. Despite the lack of rigorous studies and testing, empirical observations and extensive experience by WDFW local managers indicate vulnerable native biota is preserved when fish densities are kept low, even when fish are continually present. Some managers also believe allowing fish abundance to drop helps prevent overuse or overfishing, particularly on remote, small lakes that receive little general recreational use, or in areas that are not close to high density urban population centers. Selection of fish species to stock is of paramount importance due to the differing potential for natural reproduction between species and strains, and the nullifying effect of excessive reproduction on a manager's ability to control continuous fish presence or density.

Recommendation #3a: If human overuse is a problem at some lakes, WDFW local managers should continue to coordinate with USFS or other land managers to devise methods or approaches that limit human use without singling out recreational anglers. (In most lakes that receive moderate to heavy recreational use, fishing is an incidental activity, and fish absence would make little difference in overall use impacts.) Where angling use levels are demonstrated to be excessive (e.g., causing significant resource damage), managing for fluctuating fish density should be given serious consideration. This should only be considered where angling is the primary recreational use of the lake.

Recommendation #3b: As a general guideline, high lakes should be managed for a total standing trout density of no more than 50 to 100 fish per surface acre. It is recognized that this varies greatly, with target densities ranging from 10/ac to several hundred/ac. Local managers should never stock at more than 100/ac unless the lake has received a complete survey, and its physical, chemical, and biological characteristics indicate it can support higher densities without long term ecological harm.

Recommendation #3c: As a general rule, fish species and strains should be stocked which have a demonstrated **in**ability to successfully reproduce in Washington's high lakes. New species or strains should never be stocked into a lake that has not received a complete survey (see #3b, above). Exceptions to this rule could include lakes which do not have surface outlets and have no spawning habitat, or lakes where limited reproduction by a top predator may be desired for long term biological control (see Section 5.7.2).

WDFW local managers have experienced numerous incidents where the public has illegally stocked lakes that had a history of supporting fish, but were fishless for varying lengths of time, and for various reasons. Most experienced managers, when polled, agreed that allowing a large percentage of lakes to return to a fishless condition would lead to a marked increase in illegal stocking. Much of this stocking would likely be with fish species that would establish reproducing populations, thus extending the geographic extent of conditions that impact native biota.

Recommendation #4: The number of lakes being managed for quality, low-density trout fisheries should not be allowed to drop below current levels in order to meet the ever-increasing demand for back country angling recreation. Lakes which currently support excessively abundant fish species should be given chemical or biological treatments to reduce fish abundance. Some problem lakes should be restored to a fishless condition, and others should be managed for low-density, quality fisheries. Outreach and public education efforts should be directed to address public perception problems regarding the ecology of fish in Washington high lakes; an important theme would be the often-irreversible damage illegal stocking can cause.

Fish species and strain diversity is felt to be a very important attribute of the WDFW high lake program, not only by local managers, but also by the sport fishing public (Curtis and Erickson 1992). Diversity in the program was identified as a goal in earlier planning (WDG 1981). Recent use of exotic species and strains in carefully selected lakes has not been shown to have adverse effects, but on the contrary, have either added diversity to the catch, or had varying levels of effectiveness in controlling stunted fish populations (see Section 5.7.2).

Recommendation #5: Use of fish species and strains that are not native to Washington or specific drainages should be allowed for special and specific management objectives under circumstances where the fish cannot emigrate from, or be washed from the lake.

Genetic impacts on native fish from trout or char stocked into high lakes have not been demonstrated in Washington. (There has, however, been much speculation on the subject.) The presence of some species (eastern brook trout) or strains (westslope cutthroat) in streams below stocked high lakes may be evidence of dropout. The long history of stocking of various species and strains into headwater streams in the early part of the 20th century makes this determination problematic in most cases. Nevertheless, WDFW managers do not want stocked fish interacting with downstream native fish populations.

Recommendation #6: *WDFW local managers should practice continued diligence when preparing stocking allotments to be certain that species and strains stocked do not pose a significant risk of interbreeding with native fish in downstream areas*. Species that pose the most risk (e.g., eastern brook trout or westslope cutthroat) should be stocked only in lakes where they are currently present in low numbers, or where they physically cannot migrate or be washed out of the lake.

Local biologist managers have generally determined the stocking methods that provide the best fry survival, and that are most cost-effective for their areas. The most significant remaining problem is quality control of the stocking database. Most, if not all local managers maintain accurate records; minor problems occur when data entry is made in the Olympia headquarters, and quality control checks by the local management staff on the central database are inefficient or non-existent.

Recommendation #7: Regional office staff should have the ability to query and edit the central stocking database. All hatchery stocking reports should be reviewed by the local managing biologist for accuracy before they are forwarded to Olympia for entry into the central database.

Although the agency Beaver has avionics that can be programmed to place the airplane over the lake/s to be stocked, an experienced passenger should accompany the pilot on those trips where there is even a slight chance that the wrong lake could be stocked. These are usually instances where several small lakes lie in a tight cluster. An "expert passenger" policy would essentially eliminate the risk of stocking the wrong lake.

Recommendation #8: The district fish biologist, or other individual thoroughly familiar with the water/s to be stocked, should accompany the fixed wing or helicopter pilot on stocking runs where there is any potential for an inability to correctly identify the target water.

5.5 HATCHERY PRODUCTION PROGRAM

As mentioned in Section 2.0, trout culture and subsequent stocking into Washington high lakes preceded the establishment of the Washington Department of Game in 1933 by many years. A partial history of stocking by other agencies is given in Table 18 to illustrate this point. The following section will broadly review the WDFW cultural program over the past 20 to 30 years, and provide an emphasis on current practices.

Table 18. Early Stocking of Washington High Lakes by the United States Forest Service, National Park Service, and the U.S. Fish And Wildlife Service.

Years	Agency	Number of Lakes Stocked	Fish Species	Number of Fry Stocked
1914 -	USFS*	53+	EB, KO, RB, CT	720,175
1918 – 1973	NPS	50	EB, RB, CT	429,620
1956	USFWS	4	EB	45,430

* The US Forest Service continues to stock high lakes in cooperation with WDFW.
Sources of data are archival stocking records from WDFW and NPS.

Fry stocked into Washington's high lakes are produced from either captive brood stocks, or semi-wild fish from broodstock lakes. Exceptions are exotic species such as lake trout or golden trout that are periodically imported from other western states, and test introductions of unusual species or hybrid strains (e.g., atlantic salmon, steelhead x golden hybrids, etc.).

5.5.1 Stocking Statistics

Early recognition of the need to maintain low-density fish populations in Washington high lakes is reflected in a plot of the total number of fry stocked annually (Figure 14). The sharpest declines are with species that are known to reproduce, creating conditions that are adverse for native invertebrate and amphibian biota.